**IN THE UNITED STATES DISTRICT COURT**
**FOR THE NORTHERN DISTRICT OF OKLAHOMA**

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|---|---|---|
| **STATE OF OKLAHOMA, *et al.*,** | ) | |
| | ) | |
| ***Plaintiffs*,** | ) | |
| | ) | |
| **v.** | ) | **Case No. 4:05-cv-00329-GKF-PJC** |
| | ) | |
| **TYSON FOODS, INC., *et al.*,** | ) | |
| | ) | |
| ***Defendants*.** | ) | |
| | ) | |

**DECLARATION OF DR. GLENN JOHNSON, Ph.D.**

1. My name is Glenn Johnson. I am President of GeoChem Metrix, Inc. in Sandy Utah, and I am a Research Associate Professor at the Energy & Geoscience Institute at the University of Utah, with a faculty appointment in Department of Civil and Environmental Engineering at the University of Utah.

2. I have been retained by the Defendants in this matter to review and assess the principal component analysis testimony offered by Plaintiffs' consultant Dr. Roger Olsen.

3. I previously authored and submitted to my clients an expert report detailing my work and conclusions in this matter. I understand that this report was served on Plaintiffs. I incorporate that report herein by reference.

4. If called to testify at trial, I would testify consistent with the opinions expressed in that report.

I declare under penalty of perjury that the foregoing is true and correct.

Executed 4th June, 2009.

Glenn Johnson
University of Utah

# Rebuttal Report
# Principal Components Analysis of Geochemical Data from the Illinois River Watershed
## Northwest Arkansas and Eastern Oklahoma

**Prepared for:**
Tyson Foods, Inc.
Tyson Poultry, Inc.
Tyson Chicken, Inc.
Cobb-Vantress, Inc.
Cal-Maine Foods, Inc.
Cal-Maine Farms, Inc.
Cargill, Inc.
Cargill Turkey Production, LLC
George's, Inc.
George's Farms, Inc.
Peterson Farms, Inc.
Simmons Foods, Inc.
Willow Brook Farms, Inc.

**Prepared by:**
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November 21, 2008

Glenn W. Johnson, Ph.D.

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# Appendices

# 1.0 Introduction and Overview

This report provides a critical review and rebuttal to the opinions of Dr. Roger L. Olsen of CDM Companies, Inc. (Olsen, 2008a), as well as a reanalysis of the data upon which his opinions are based. The issue in dispute is the degree to which a series of principal components analysis (PCA) runs conducted by Olsen, support his conclusions with regard to sources of phosphorus, bacteria and other constituents in the Illinois River Watershed in Northwest Arkansas and Eastern Oklahoma. A map of the study area is shown as Figure 1-1.

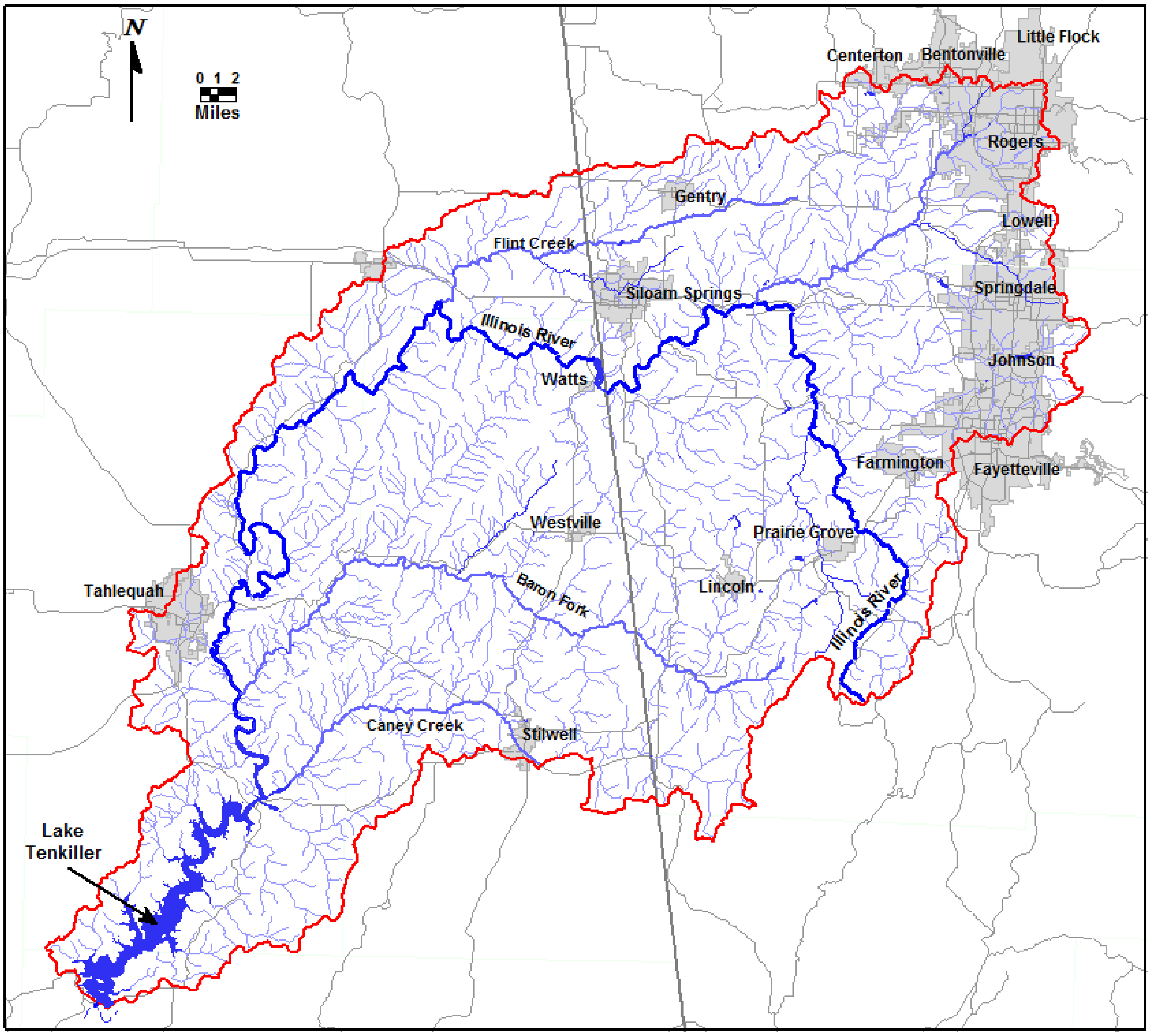


**Figure 1-1.** Site map showing rivers, creeks, lakes and cities/towns.
Gray shaded areas indicate regions of human population density > 400 people/mi$^2$, based on ESRI (2006) data.

Olsen's primary opinion based on his PCA, is summarized at the beginning of his report, in the following quote:

> *"Principal components analysis (PCA) identified two major sources of contamination in the IRW: poultry waste disposal and WWTP discharges. Poultry waste is by far the dominant contamination source in the IRW when compared to other sources. Cattle waste contamination was unique from both poultry waste and WWTP effluent, and was identified in some samples with documented cattle manure contamination. However, chemical contamination from cattle waste is not dominant in the basin and only represents a minor source. In the PCA, the chemical and bacterial composition of poultry waste creates a distinct chemical signature that contains both phosphorous and bacteria."*[1]

Olsen supports his application of PCA to IRW data sets by citing a number of papers in the literature where PCA and related methods were applied to environmental chemical data. There are indeed, many PCA applications in the literature. I have published such papers myself.[2] Olsen has not.[3] I have also served as a peer-reviewer for PCA case-study papers submitted to a number of journals.[4] There are numerous pitfalls for the unwary and/or inexperienced PCA practitioner. The mere existence of the literature cited by Olsen does not validate his work, nor does it give him license to err in PCA implementation, to misinterpret the results or to conceal lines of evidence that contradict his opinion. In this report, I will show that Olsen did all of this, and that his PCA does not identify sources of contamination in the IRW. Rather, it reflects the degree to which a small handful of chemicals exhibit a preference to be in solution, or to be associated with the particles in the suspended solids phase.

## 1.1 Qualifications

The conclusions and opinions in this report are based on my professional experience and education, and my opinions are supported to a reasonable degree of scientific certainty. My expertise is in the area of environmental forensics, with a particular focus on the application of multivariate statistical methods (including PCA) to environmental geochemical data. I received my M.S. in Geology at the University of Delaware in 1988 and my thesis focused on multivariate statistical analysis applied to geological data. I spent seven years in environmental consulting with Roux Associates, Inc. (West Deptford, New Jersey) and McLaren/Hart Environmental Engineering, Corp (Philadelphia, PA). During that time, I worked on a number of environmental contamination projects under a variety of regulatory authorities, including CERCLA, RCRA and a number of State regulatory authorities. I received my Ph.D. in Geological Sciences from the University of South Carolina in 1997, and my dissertation concerned development and application of a PCA based receptor modeling method to environmental geochemical data. Since 1995, I have been a research faculty member at the Energy & Geoscience Institute (EGI), Department of Civil and Environmental Engineering at the University of Utah. My current position is Research Associate Professor. My research at EGI focuses on development and deployment of multivariate statistical methods in geology, environmental chemistry, and environmental forensics. My environmental forensics work has focused on sources, fate and

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[1] Olsen (2008a). p. 1-2. Bullet 3.

[2] Johnson, et al., 2007; Magar, et al., 2005; DeCaprio, et al., 2005; Johnson and Ehrlich, 2002; Johnson, 2002; Johnson, et al., 2000; Jarman, et al., 1997; Dore, et al., 1996; Ehrlich, et al., 1994.

[3] See Olsen 9/11/08 Deposition. p. 306. Lines 2-8.

[4] See Johnson CV: Appendix B, p. 14.

alteration of contaminants in soil, sediment, water and biota. I am the President and Chief Scientist of GeoChem Metrix, Inc. in Sandy, Utah - a service firm that specializes in analysis of chemical data and environmental forensics, and it is under that affiliation that this work has been performed.

I have spent a good portion of my career focusing on the development and deployment of PCA-based methods in environmental geochemistry and environmental forensics. I have published methodological papers/tutorials on the subject, as well as case-study/application papers. I have taught short courses on multivariate methods (including PCA) for the International Society of Environmental Forensics, the Association of Environmental Health and Soils, and the Society of Environmental Toxicologists and Chemists.

My curriculum vita is included as Appendix B of this report. My CV includes all of my publications as well as a summary of testimony provided in other cases. My billing rate for work conducted in this matter is $175/hour for data analysis and report preparation, and $225/hour for deposition and trial testimony

## 1.2 Data and Information Considered

The focus of my work on this project has been to review and critique the multivariate data analyses presented by Roger Olsen in his May 14, 2008 report (Olsen, 2008a). Thus, a primary objective of my work was to first understand exactly what data sets were used and considered by Olsen. I identified the following data sets produced by Olsen and/or his CDM colleagues, as summarized below.

The data considered in Olsen's PCA runs are contained within a Microsoft Access database entitled IllinoisMaster.mdb.[5] For use in his PCA, two primary subsets of the database were extracted and saved in the Excel files named: (1) PCA_Main_Database_Water.xls; and (2) PCA_Main_Database_Solids.xls.[6] These files contain approximately 50 data fields. Individual Excel subdatabase spreadsheets were then extracted from these files for use in PCA.[7] These files contained data for nine variables.[8] The PCA reproductions presented in this report start with these subdatabase files. Cowan (2008) addresses the degree to which these files can be recreated from the original Microsoft Access database.

Using these files as his source data, Olsen performed PCA on a number of permutations of the water data that are presented in his report (22 PCA runs – numbered SW1 through SW22) and solids data (8 PCA runs – numbered SD1 through SD8).[9] These individual PCA runs differed by (1) whether solids or water samples were considered; (2) which groups of samples were included in the analyses (i.e. USGS base flow samples, Lake Tenkiller samples, etc.); (3) which analytes (chemical parameters and bacteria) were included in the analyses; and (4) the criteria used for inclusion of samples with missing data.

The numbers of samples and analytes in each PCA run are summarized in Olsen's Table 6.11-7a and 6.11-7b. Individual input matrices and results for each PCA run were provided by Olsen in

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[5] Olsen (2008a). pp. 4-1 to 4-2.
[6] Olsen (2008a). p. 6-35.
[7] Olsen (2008a). p. 6-39.
[8] Subdatabase files contained data for the following nine fields: EDA_Group; EDA_Sample; EDA_Location; EDA_Variable; EDA_Value; EDA_ValOp; EDA_UnitsID; EDA_Y; and EDA_X. Olsen (2008a) pp. 6-36 to 6-37.
[9] In addition, there PCAs run in preparation for the February Preliminary Injunction (PI) hearing, and "preliminary" PCAs run after the PI, that were not includes in Olsen's report. See Olsen deposition testimony September 10 and 11, 2008. P. 371-376.

the form of spreadsheets with filenames keyed to the PCA run numbers. For example, for Olsen's primary water PCA run SW3 (573 surface water samples, 26 analytes) the input data matrix was included in Olsen's document production as the file '*Crosstab_Water_0427_SW_3.xls*'. The results (scores, loadings, PC coefficients, eigenvalues, percent variance explained, and rotations) were included in the produced file '*Results_Water_0427_SW_3.xls'*.

The results files contain the digital data used for Olsen's PCA related graphics. These files were useful in evaluating Olsen's PCA, because it allowed plotting of data in alternative ways to that presented by Olsen. For example, Olsen claims to have done a spatial analysis whereby he evaluated the efficacy of his poultry fingerprint criterion by comparison to purported ground-truth data, such as poultry house density data.[10] This was based on his opinion that poultry house density is a surrogate for poultry waste land applications.[11] Elsewhere in his report, Olsen presents a map of poultry house density data, but curiously, he never shows PCA results plotted over that basemap. As Olsen's poultry house data was produced as GIS shapefiles, it was relatively easy to re-plot Olsen's PCA results on his poultry-house density basemap.

The data described above were produced by Olsen in Excel, SYSTAT and Microsoft Access, and GIS (shapefile) formats. In addition I have reviewed Olsen's correspondence and data provided in his considered materials, two errata submitted by Olsen (dated July 25, 2008 and September 24, 2008), his testimony in connection with the Preliminary Injunction ("PI" - February 2, 2008 deposition testimony; February 21-22 hearing testimony), and his September 2008 deposition testimony. I have also considered scientific literature that I have acquired in my experience, and I visited the Illinois River watershed on July 16, 2008.

## 1.3 Opinions

My primary opinions are summarized below. The bases of these opinions are expanded upon throughout the remainder of the main body of this report and Appendix A.

- **Fallacy of the "Unique Poultry Waste Signature."** Olsen's PCA cannot differentiate between poultry and other sources in the IRW. Olsen's sampling included collection of a few samples designed to characterize sources other than poultry (e.g. cattle and waste-water treatment plants), but his PCA cannot distinguish between these source categories. In addition, there are multiple other sources not considered by Olsen at all (spray irrigation, sludge application, biosolids application, nursery runoff, golf courses, wildlife, swine lagoons, septic systems, runoff from dirt roads, and commercial fertilizer application).[12]
- **Errors in Assumptions of the PCA Method**. Olsen made fundamental errors related to basic assumptions of the PCA method. The most consequential of these were (1) his assumption that unique source signatures will be conserved in the environment; and (2) the assumption that a principal component *equals* a source-related fingerprint.[13] These assumptions are addressed in more detail in Appendix A.
- **Errors of PCA Implementation**. Olsen made a number of errors in implementation of PCA: (1) he ignored results of goodness-of-fit diagnostics that suggested that he should retain more than 2 principal components; (2) the data transformations used were not

[10] See Olsen (2008a). pp. 6-34. Steps 12 and 13.
[11] Olsen (2008a). p. 6-30. 4th paragraph.
[12] Olsen Deposition. 9/11/08. pp. 521-534.
[13] Olsen (2008a). p. 6-59. Summary Observations. 1st sentence.

appropriate for this type of analysis; (3) rather than use PC scores calculated and reported by SYSTAT, Olsen chose to calculate PC scores himself, and in the process he did the calculations incorrectly; and (4) he did not evaluate goodness-of-fit on a variable-by-variable basis, so he is apparently unaware that several parameters that he considers diagnostic of his "*unique poultry waste signature*" (bacteria, arsenic, copper, zinc) exhibit a poor fit in his model. These mathematical/methodological problems are addressed in more detail in Appendix A.

- **Data Quality Problems.** There are problems with the quality of this data set, such that it is doubtful that a correctly implemented PCA would have yielded results that would allow differentiation of source fingerprints. Problems include the potential bias introduced by multiple labs using multiple analytical methods, a high incidence of missing data (especially for bacteria), missing data substitution strategies, and sample representativeness problems. The basis of this opinion is addressed primarily within Appendix A of this report, and is also addressed by Cowan (2008).
- **Major Contradictions to Olsen's Interpretations and Opinions**. Even if we ignore the problems of data quality, assumptions, and implementation, and accept Olsen's PCA results at face value, a detailed review of Olsen's interpretations reveals major contradictions. Olsen was aware of many of these, but presented only examples that supported his opinion. In one instance, Olsen changed the representation of results on a map, such that his PCA results appear to support his interpretation. In so doing, he never disclosed that subjective decision to the reader.
- **Failure to Recognize Influence of Total Concentration and Geochemical Partitioning on the PCA**. By assuming from the outset that source signatures control this data set, Olsen completely missed the two primary controls on the surface water and groundwater data sets: (1) total concentration; and (2) how chemicals redistribute in the environment according to their affinity for the dissolved phase versus association with suspended particulate matter. Olsen's PCA cannot be used to infer <u>any</u> source of contamination to the IRW, let alone poultry.

# 2.0 PCA Summary and Its Application by Olsen

## 2.1 Principal Components Analysis (PCA) Overview

Olsen conducted a series of principal components analyses (PCA) of water and solids data. The objective of PCA is to reduce the dimensionality of a data set in which there are a large number of interrelated (i.e., correlated) variables, such that similarities and differences between samples may be viewed on a single plot, with minimal loss of information. This dimensionality reduction is achieved by transforming the data to a new set of uncorrelated (i.e. mutually orthogonal) reference variables, which are termed principal components (PCs). The PCs are sorted such that each in turn, accounts for a progressively smaller percentage of variance. If the significant sources of variability can be accounted for by a small number of PCs, then relationships between multivariate samples may be assessed by simple inspection of a 2 or 3-dimensional plot, referred to as a principal components scores plot (*PC scores plot*). An example scores plot is shown below (Figure 2-1).

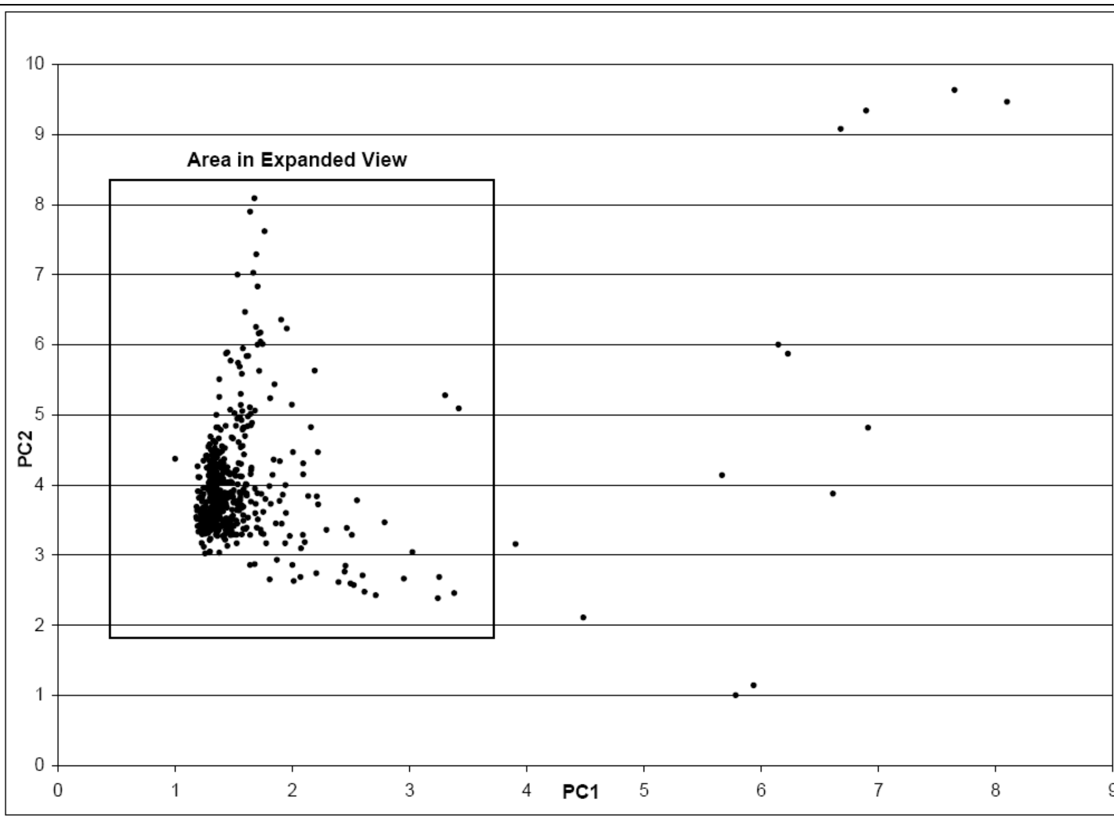


**Figure 2-1.** Olsen's scores plot for PCA run SW3 (full range view).
This figure is a direct copy of Olsen Figure 6.11-18a.

Figure 2-1 is a direct copy of Olsen's Figure 6.11-18a, and is a scores plot from Olsen's primary PCA run: SW3. Each of the black dots on this plot represents one of the 573 samples in SW3. The main thing to keep in mind in viewing such a plot is that samples that plot close to each other have similar chemical compositions. Samples that plot a great distance from each other have different chemical compositions.

## 2.2 Olsen's PCA Methodology

The term "PCA" is not a definitive statement of one's methodology. There are numerous data pretreatment methods, transformations, goodness-of-fit diagnostics, and other data analysis options that can be done under the umbrella term "PCA." Therefore, merely saying that one has performed a PCA is insufficient to understand exactly what calculations might have been done. As such, Olsen's actual PCA methods are provided in Appendix A. This includes a detailed discussion of the mathematics of PCA, a discussion of the difference between PCA and factor analysis[14] and a presentation of the calculations actually employed by Olsen. For a more detailed discussion of the general methodology of PCA and related methods, the reader is referred to a book chapter I wrote on the subject.[15]

Olsen performed his PCA using three software tools: Microsoft Excel, SYSTAT and EDAnalyzer. Excel was used to perform transformations, prepare the data for the actual PCA calculation, and calculation of scores on the back-end of the PCA. The PCA itself was done using the commercial statistical software package: SYSTAT (specifically SYSTAT's Factor Analysis module). In addition, Olsen used an in-house, proprietary software program ('EDAnalyzer') which is an Excel Add-In that reportedly serves as an interface to control graphical output and the various inputs/outputs between Excel and SYSTAT. EDAnalyzer was developed by CDM, and was used to do exploratory analysis, set up instructions for Excel, and set desired parameters for subsequent PCA of the data.[16]

### *2.2.1 Results Presented by Olsen*

PCA results were provided in the form of data files as described in Section 1.2. Olsen presented these results graphically in a number of formats as follows:

- **Scree Plots**. These plots show the percentage of variance (a function of eigenvalues) associated with each principal component. The percent variance is plotted as a ski-slope shaped curve/line graph (e.g. Olsen Figures 6.11-1, 6.11-3, 6.11-5, 6.11-7 and 6.11-9). Data for these graphs are included in results spreadsheets under the row heading "Percent of Total Variance Explained."
- **Percent Variance Bar Graphs**. These bar graphs show the same information as a scree plot, but the data is plotted alternatively as a bar graph, rather than a line graph (e.g. Olsen Figures 6.11-2, 6.11-4, 6.11-6 and 6.11-8).
- **Loadings Bar Graphs.** These plots graphically illustrate the principal components loadings, which are correlation coefficients of the principal components with respect to individual chemicals included in the analysis (Olsen Figures 6.11-10, 6.11-12, 6.11-14a, 6.11-14b, 6.11-16, 6.11-18).
- **PC Coefficients Bar Graphs.** Principal component coefficients are equal to the loadings divided by the corresponding eigenvalues. Visually they should look identical to the loadings bar graphs, the only difference being that scaling by eigenvalues changes the scale of the y-axis.
- **Scores Plots.** Scores values are included in each results spreadsheet, and were used to plot principal components scores plots (Olsen Figures 6.11-18a-e, 6.11-19a-d, 6.11-20a-f, 6.11-21a-d, 6.11-22a-d, and 6.11-25). One of Olsen's scores plots (from his PCA run SW3) is presented above as Figure 2-1.

[14] Olsen maintains that he is doing *principal components analysis*, not *factor analysis*. The distinction between these (and which one Olsen used) was a point of contention during the PI process. As such, Appendix A addresses the distinction between the two, as well as discussion of the reasons for the stigma associated with '*factor analysis*.'

[15] Johnson, et al. (2007).

[16] Olsen (2008a) p. 6-36; p. 6-40. Deposition Testimony (9/11/08). p. 308-313.

- **Scores Maps.** One of Olsen's most consequential interpretations is that principal component 1 (PC1) is equivalent to "*poultry waste*."[17] This is an entirely subjective and unsupportable conclusion that will be addressed in detail elsewhere in his report. Be that as it may, given that interpretation, Olsen established a criterion whereby samples with PC1 > 1.3 were considered to be '*poultry waste impacted*' and he presented maps whereby samples above this threshold are shown as red-shaded circles. Samples with PC1 scores < 1.3 are shaded green. These maps are referred to within my report as Olsen's "red-dot / green-dot maps."

In addition to the graphics summarized above, the results of Olsen's PCA runs (scores, loadings, PC coefficients, eigenvalues, percent variance explained, and rotations) were provided digitally in a series of Excel files, the names of which are keyed to the PCA run number (e.g. SW3 results are in file '*Results_Water_0427_SW_3.xls*'. The results files contain the digital data used for most of the PCA related graphics listed above. The PC scores for each of Olsen's four major PCA runs were also included in Appendix F of his report.

### 2.2.2 Methodological Problems

On pages 6-32 through 6-66 of his report, Olsen describes his PCA methods (data management practices, preparation steps, data preprocessing options, calculations, back-calculations, and interpretations). To check these described methods I attempted to reproduce Olsen's primary PCA run (SW3) using the normalizations and transformations that he indicated. The method descriptions in Olsen's report were ultimately insufficient to reproduce his analyses. I was able to fill in these gaps by trial and error, by matching matrices to the results reported in Olsen's production material. To the extent that I found errors or gaps in his method descriptions, I have clarified what Olsen actually did in Appendix A. In so doing, I identified a number of key errors and concerns with respect to Olsen's assumptions, the quality of his data, his PCA implementation, and its general application to this environmental chemical data set. These problems are summarized below, and are outlined in detail in Appendix A.

#### 2.2.2.1 Faulty Assumptions

Olsen's PCA carries with it, two basic assumptions that are fundamentally wrong.

- Reification of Factors. *Reification* is a term that refers to the assumption that principal components or factors are "things" that can be *equated* with physical or chemical phenomena. They are not. Rather, principal components are abstract sets of coordinates that allow us to plot data on simple two or three dimensional graphs. But Olsen consistently interprets PC1 as "*poultry waste*" and PC2 as "*waste water treatment plant effluent.*"[18] *Reification* of principal components and factors has been criticized in the literature for more than 25 years. (See Appendix A: Sections A1.2, A1.3; A1.4.2, A2.5, A2.5.1).
- *A priori* Assumption of a Source-Driven System. PCA and related methods have been successfully used in the literature to identify chemical patterns related to source. But source patterns do not always drive a PCA. What does drive is systematic variability, regardless of where it comes from. PCA can just as easily reflect alteration processes or even systematic error or bias. It depends on the data set being studied. But Olsen never discusses or explores his PCA interpretation in any context other than sources. Therefore, his interpretation carries the implicit assumption that differences in chemical patterns in

[17] Olsen (2008a). p. 6-60. Also see Figure 6.11-18c.
[18] Olsen (2008a). p. 6-59. Summary Observations. 1st sentence.

the IRW are due to differences in sources, and only sources. But Olsen has acknowledged that some chemicals used in his PCA (e.g. sodium) are preferentially found in the dissolved fraction of water[19] and that others (e.g. iron and aluminum) are preferentially associated with suspended sediment in water.[20] When Olsen's PCA is evaluated in context of preferential affinity of these analytes, his so called "*poultry signature*" is actually related to nothing more than suspended particulate matter in a sample. This issue is explored further in Section 4.2.

#### 2.2.2.2 Data Concerns

There are numerous problems with the data set analyzed by Olsen using PCA, such that it is doubtful that a correctly implemented PCA would yield results that would allow inference of source fingerprints with any degree of confidence. These issues are summarized below, and are discussed in detail in Appendix A (Section A2.1). These issues are also addressed in the expert report of Cowan (2008).

- High Incidence of Missing Data. CDM and Lithochimea collected 2,325 individual water samples that were originally considered for use in Olsen's primary PCA run (SW3: see Table 2-1). Only 267 samples (11.5%) had full data records for all 26 variables used in Olsen's PCA run SW3. Olsen got the number of samples in SW3 up to 573 by allowing samples with up to 6 missing data points in the analysis. Of the 26 variables in SW3, bacteria (total coliforms, E. coli, enterococcus, fecal coliform) were the most problematic in terms of missing data. The percentage of missing data for bacteria variables ranged from 28 to 41 percent of the samples (see Appendix A, Section A2.1 and Table 2-1).
- Missing Data Substitution. In order to be able to use samples with up to 6 missing data points, Olsen had to come up with a missing data substitution scheme. The scheme employed was substitution of the mean (average) for all samples in the data set where that variable was not missing. This presents a series problems that discussed in more detail in Appendix A (Section A2.1).
- Multiple Analytical Methods. Phosphorus (P) is one of the primary chemicals of concern in the IRW study. However, the P data in Olsen's data base were run by different labs and by different methods. To the extent that there is a potential bias between these methods (and Olsen acknowledges that there is) this could contribute systematic variability to a PCA (Appendix A: Section A2.1).
- General Data Management Issues. From a database management standpoint, there are problems with the reproducibility of the data going from the Access database into the PCA, as outlined by Cowan (2008).

#### 2.2.2.3 Errors in Calculation and Implementation

Olsen demonstrates a lacks of understanding and/or experience in implementation of PCA. Major mistakes in implementation include:

- Errors in Calculation of Principal Component Scores. While Olsen's software package SYSTAT reports PCA scores, Olsen did not use them. Instead he calculated them himself in Excel. In so doing he failed to correctly back-calculate his data (see Appendix A: Section A2.3).
- Failure to use more sophisticated PCA goodness-of-fit diagnostics. Olsen relied primarily on the percent variance criterion for determining the number of significant principal

[19] Olsen (2008a). p. 3-18. 4th paragraph. Olsen Deposition. 9/10/08. p. 116-117.
[20] Olsen Deposition. 9/10/08. p. 77.

components, and as a result his analysis focuses primarily on 2 PC models. In Appendix A, using a graphical variable-by-variable goodness of fit diagnostic method, I show that Olsen's 2 principal component model for surface water exhibits a very poor fit for several variables that he claims are important constituents of his "*unique poultry waste signature*" (arsenic, copper, zinc, total coliforms, E. coli, enterococcus, fecal coliforms). Olsen was aware of this method, but opted not to use it. Olsen was also aware of SYSTAT results indicating up to 5 principal components, but he ignored that information. (Appendix A: Section A2-4).

#### 2.2.2.4 Errors in Interpretation

Olsen's PCA interpretations are not consistent with the purported independent ground-truth information (poultry-house density data) presented in his report. As a result, what Olsen calls a '*unique poultry-specific biological and chemical signature*' is neither unique nor poultry-specific. Olsen either failed to recognize or failed to disclose information that contradicted his opinion. These issues are discussed in more detail in the summaries of Olsen's major PCA runs (Section 2.3) and in discussion of the major contradictions in Olsen's theory (Section 3.0).

#### 2.2.2.5 Failure to Adequately Characterize Other Sources

In Olsen's SW3 PCA run (surface water samples), collected sample to characterize the signature of potential sources. The vast majority of these were presumed from the outset to reflect the impact of the application of poultry-litter impact (64 edge-of-field samples).[21] Only six samples were collected with the intent of characterizing other potential sources. Two were collected with the intent of characterizing the impact of cattle (surface waters from cow-pastures where poultry-litter had never been applied).[22] Four were collected to characterize waste-water treatment plant samples (WWTP) effluent.[23] Other potential sources in the watershed were never evaluated, sampled or characterized (at least not for the 26 parameters used in Olsen's PCA). In deposition testimony, Olsen acknowledged that he had collected no samples to characterize sludge application, wastewater disposal by spray irrigation, biosolids application, nursery runoff, golf course runoff, wildlife feces, swine lagoon input, septic systems, runoff from dirt roads, or commercial fertilizer applications.[24]

[21] Olsen (2008a). p. 6-6 & Figure 6.4-2a. Olsen Deposition. 9/10/08. pp. 51-52.
[22] Olsen Deposition. 9/10/08. pp. 53. (Lines 1-5).
[23] Olsen (2008a). p. 6-4.
[24] Olsen Deposition. 9/11/08. pp. 521-534.

## 2.3 Summary of Olsen's Major PCA Runs

Olsen did 22 PCA runs for water, and 7 PCA runs for solids. The results of most of these are never discussed in Olsen's report. His opinions are based primarily on "*four major PCA runs*"[25] designated as such because they are "*the most important to the investigation or project objectives.*"[26] The four major runs cited by Olsen were SW3, SW17, SD1, and SD6. I have added a fifth to that list (SW22) because it forms the basis of Olsen's opinion regarding the impact of cattle in the IRW. These five PCA runs were included in a category Olsen refers to as "*investigative runs,*" implemented for the direct purpose of source identification in the watershed.[27] Most of the other PCA runs fall into a category Olsen calls '*sensitivity runs*' which were implemented to evaluate the effect of different permutations of the database (i.e. number of parameters, missing data cutoff criteria, groups or types of samples included, etc.). Each of Olsen's five major PCA runs are discussed in the remainder of this section of the report, along with a critical review of the opinions that Olsen draws from them.

### 2.3.1 SW3: Surface Water

SW3 was the PCA run relied upon by Olsen to reach the most consequential opinion of his report: that poultry was "*by far the dominant contamination source*" in surface waters of the IRW.[28] As such, this is the PCA run that I address in greatest detail throughout my report. Table 2-1 shows the total number of samples considered (2,325) as well as the number of sample per group (EDA_Group). Only 573 samples met Olsen's missing data criterion. Even then, some variables had much higher incidence of missing data, especially bacteria (coliform, E. coli, enterococcus, and fecal coliform). Variables missing in more than 10% of the samples are shown in red text. Appendix A (Section A2.1) includes further discussion of the missing data problem and the substitution method used by Olsen.

Olsen performed PCA on this 573 by 26 matrix after implementing a log transformation. Transformations are discussed in Appendix A (Section A2.2). He implemented PCA using the Factor Analysis module within the commercial software package SYSTAT (Section A2.3). Olsen used the SYSTAT-reported eigenvalues, percent variance accounted for, loadings, and coefficients (Section A2.3) but chose to calculate scores himself (outside of SYSTAT – in Excel) and in so doing failed to undo the log transformation (Section A2.3). SYSTAT's criteria indicated the presence of five significant principal components, but Olsen ultimately ignored that information and reports only the results of the first 2 principal components. His justification for a 2 PC model was that it accounted for 56.2 percent of the variance.[29] In Appendix A (Section A2.4) I discuss this decision, and I evaluate the goodness of fit of Olsen's SW3 PCA run using more sophisticated methods. In that discussion, I make it clear that for several key parameters that Olsen considers important parameters in his *unique poultry waste signature*[30] (copper, arsenic, zinc, and four bacteria variables) Olsen's 2 PC model does a poor job of recreating the original data.

The remainder of this section is a summary and discussion of Olsen's interpretation of SW3 results. Bearing in mind the numerous methodological problems discussed in Section 2.2.2, for purposes of this discussion, I take Olsen's PCA results at face value, and summarize his interpretations based on those results.

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[25] Olsen (2008a). p. 6-51. Last paragraph.
[26] Olsen p. 6-50. See also Table at the top of page 6-52.
[27] Olsen (2008a). p. 6-50. Olsen's four major PCA runs and SW22 were also considered 'investigative runs'
[28] Olsen (2008a). p. 1-2.
[29] Olsen (2008a). pp. 6-50 to 6-52. Figure 6.11-1.
[30] Olsen (2008a). p. 1-2 (3rd bullet), and p. 6-27.

**Table 2-1**. Summary of Olsen PCA Run SW3.

**PCA Run SW3**
**573** Samples
**26** Variable
= **6** Missing Data Points Allowed Per Sample

| | EDA_Group | Sample Summary: Total Number of Water Samples Available in CDM Database, for this Group | Sample Summary: Number of Samples that Meet Missing Data Criterion | Variable Summary: EDA_Variable | Variable Summary: Number of Samples with Data Reported | Variable Summary: Percent Missing Data | Transformation Used for PCA |
|---|---|---|---|---|---|---|---|
| **SW3** | SW - Edge of Field | 89 | 65 | AL_T | 573 | 0% | Log10 |
| 0427_SW_3 | SW - Lake - Tenkiller | 533 | 29 | ALKALINITY | 565 | 1% | Log10 |
| | SW - Stream - BFC | 960 | 88 | AS_T | 569 | 1% | Log10 |
| **Surface** | SW - Stream - Forest | 2 | 0 | BA_T | 573 | 0% | Log10 |
| **Water Only** | SW - Stream - HFC | 152 | 20 | CA_T | 573 | 0% | Log10 |
| | SW - Stream - High Flow - BFC | 55 | 48 | CL | 563 | 2% | Log10 |
| | SW - Stream - High Flow - HFC | 240 | 177 | **COLIFORMS** | **412** | **28%** | Log10 |
| | SW - Stream - NA | 10 | 0 | CU_T | 569 | 1% | Log10 |
| | SW - Stream - PA - BFC | 12 | 0 | **ECOLI** | **340** | **41%** | Log10 |
| | SW - Stream - PA - HFC | 22 | 0 | **ENTERO** | **410** | **28%** | Log10 |
| | SW - Stream - Synoptic | 24 | 1 | FE_T | 573 | 0% | Log10 |
| | SW - Stream - USGS - BFC | 107 | 60 | **FECAL** | **410** | **28%** | Log10 |
| | SW - Stream - USGS - HFC | 115 | 81 | K_T | 573 | 0% | Log10 |
| | SW - Stream - WWTP | 4 | 4 | MG_T | 573 | 0% | Log10 |
| | **Total** | **2325** | **573** | MN_T | 573 | 0% | Log10 |
| | | | | NA_T | 573 | 0% | Log10 |
| | | | | NI_T | 569 | 1% | Log10 |
| | | | | NO2_NO3 | 564 | 2% | Log10 |
| | | | | P_SOL_REAC | 559 | 2% | Log10 |
| | | | | P_T | 571 | 0% | Log10 |
| | | | | P_TD | 572 | 0% | Log10 |
| | | | | SO4 | 563 | 2% | Log10 |
| | | | | TDS | 538 | 6% | Log10 |
| | | | | **TKN** | **505** | **12%** | Log10 |
| | | | | TOC | 551 | 4% | Log10 |
| | | | | ZN_T | 569 | 1% | Log10 |

Information from Olsen-produced spreadsheet '*PCA_Water_Runs_Table.xls*' as attachment to 5/9/08 email from Chappell to Olsen.

Olsen began his SW3 interpretation by plotting PC loadings as bar graphs and noting which analytes had the highest loadings. A direct copy of Olsen's Figure 6.11-10 is shown below as Figure 2-2. Pointing to these bar graphs, Olsen reported a similarity between PC1 (left panel of Figure 2-2) and presumed "*poultry-waste impacted water*."[31] That led him to conclude that "*PC1 has been identified as associated with poultry waste.*"[32] Olsen follows similar logic with respect to PC2 loadings (right panel of Figure 2-2) and ultimately opined that "*PC2 has been identified as associated with WWTP effluent.*"[33]

There are serious flaws in the logic that led to these conclusions. Olsen justifies his interpretation with a poorly reasoned, apples-to-oranges comparison of loadings (presented in abstract units of the PCA: log-transformed, correlation coefficients) to chemical data (in units of concentration). But the problem goes beyond units and stoichiometry. Olsen also makes the fundamental mistake of *reification* – equating a principal component with a *thing* with physical or chemical meaning. Olsen *reifies* or equates PC1 with "*poultry-waste*", and PC2 with WWTP effluent. Reification has been criticized in the literature for more than 25 years. The problems of reification of principal components are discussed in more detail in Appendix A (Sections A1.2, A1.3; A1.4.2, A2.5, A2.5.1).

[31] Olsen (2008a). p. 6-57. 2nd paragraph.
[32] Olsen (2008a). p. 6-57. 3rd paragraph.
[33] Olsen (2008a). p. 6-57. 3rd paragraph.

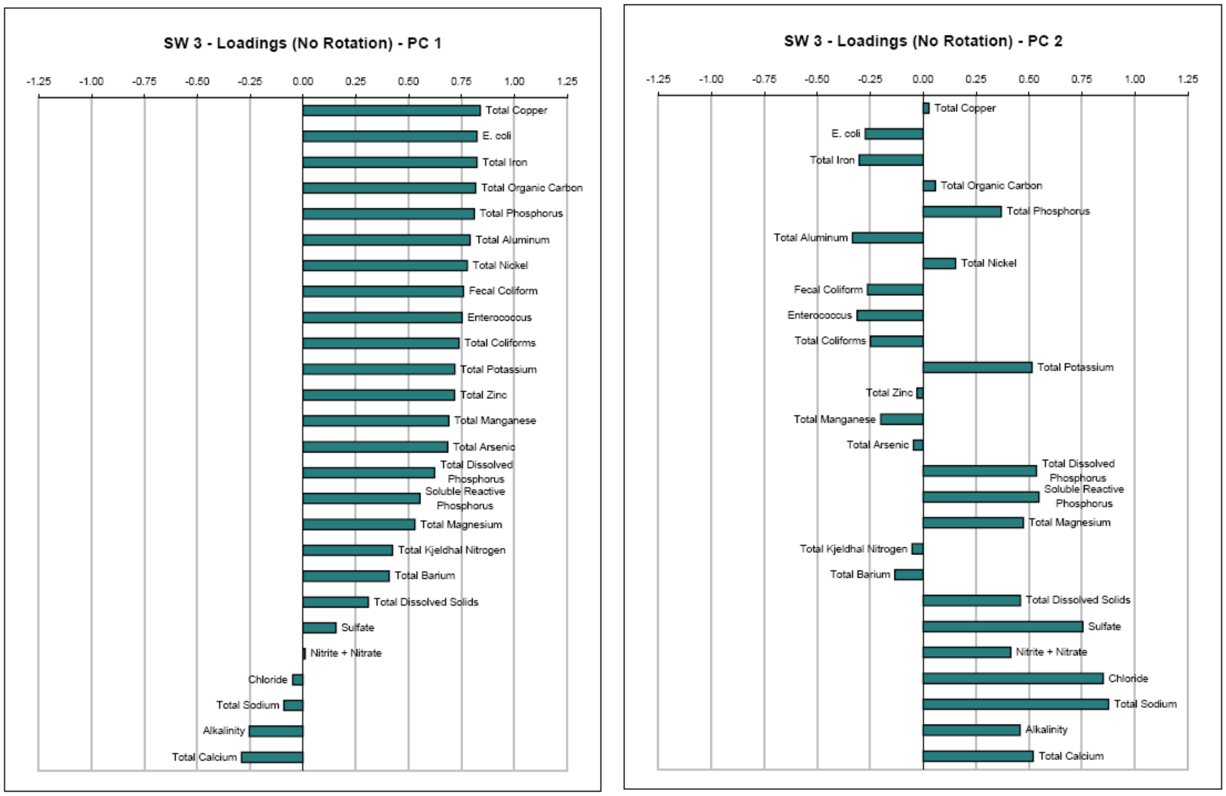


**Figure 2-2.** Olsen's loadings bar graphs for PCA run SW3.
Direct copy of Figure 6.11-10 of Olsen's Report

Based on Olsen's opinion that PC1 equals poultry and PC2 equals WWTP, he ultimately classified samples in SW3 with respect to their supposed predominant impact. Figure 2-3 is a direct copy of Olsen's Figure 6.11-18c, and shows his interpretation of the limits of dominant impact from his two supposed primary sources: "*Poultry-waste Dominant Impact*" and "*WWTP Dominant Impact*." To the reader unfamiliar with PCA, the red circled regions of Figure 2-3 may be misleading. These circles are not the objective results of the PCA method. They are not determined by SYSTAT or by any mathematical procedure. Rather, they represent a <u>subjective interpretation</u> on Olsen's part.

The limits of the two red ovals (shown graphically on the figure) were also defined numerically by Olsesn, as is seen in the quote below.

> *"The two groups were selected by examining the locations and chemistry/bacterial composition of the individual samples. <u>For the "WWTP dominant impact" group, the PC2 scores were selected to be above a value of **4.7**</u>. As shown on Table 6.11-11, samples below about a score of 4.8 are typically not in locations downgradient of WWTP discharges so cannot be impacted by WWTPs. <u>For the "poultry-waste dominant impact" group, a PC1 score of greater than **1.3** was selected</u>. This is a conservatively high value and could have been set lower to include more samples."*[34]

As is made clear in this quote, Olsen considers any sample exhibiting a PC2 scores greater than 4.7 to be impacted by WWTP effluent, and any sample with a PC1 score greater than 1.3 to be impacted by poultry.

[34] Olsen (2008a). p. 6-59 to 6-60 (emphasis added).

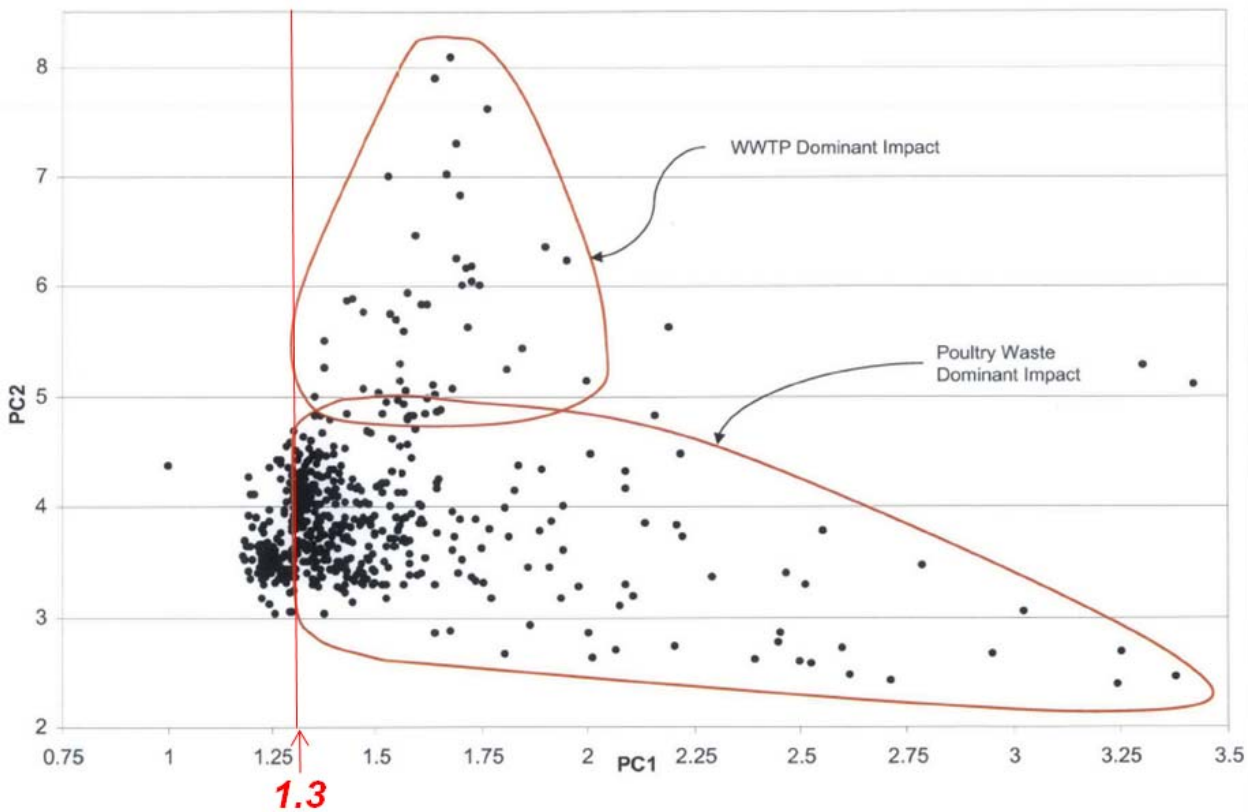


**Figure 2-3.** Olsen's PCA scores-plot for PCA run SW3 (zoomed in on 'expanded view' area). This figure is a direct copy reproduction of Olsen Figure 6.11-18c. The red ovals and annotation *"Poultry-Waste Dominant Impact"* are Olsen's. I added the PC1=1.3 line.

Olsen's conclusion of a 1.3 PC1 poultry-impact threshold (highlighted in quote above) is the most consequential decision of his entire PCA. Olsen and his colleagues have repeatedly referred to Olsen's *"poultry signature."* But such a term is not a precise description of a PCA-based criterion. Figure 2-3 clarifies Olsen's actual numerical criterion. When he and other plaintiff experts testified at the Preliminary Injunction with regard to Olsen's "*unique poultry waste signature*" [35] or "*chemical fingerprint*"[36] it is the 1.3 PC1 threshold to which they were referring. A sample that supposedly exhibits Olsen's "*unique poultry waste signature"* is a sample that plots to the right-side of the PC1=1.3 line on Figure 2-3.

This threshold is entirely arbitrary, and Olsen has acknowledged as much. He has testified that there are samples with PC1 scores less than 1.3 that he believes may be impacted by poultry[37] and he has acknowledged samples with PC1 scores greater than 1.3 that he concedes are not impacted by poultry.[38] The arbitrary nature of this threshold discussed in more detail in Appendix A (Section A2.5.2).

Part of the reason that the 1.3 PC1 threshold is arbitrary is that it is not supported by the data Olsen supposedly relied upon to validate the threshold. The basis of Olsen's conclusion of a 1.3 PC1 threshold for poultry, and a 4.7 PC2 threshold for WWTP was his "*spatial analysis.*" That

[35] See PI Hearing Transcript: Olsen at p. 806; Teaf at p. 210; Harwood at p. 672;
[36] See PI Hearing Transcript: Olsen at p. 815;
[37] Olsen Deposition. 9/11/08. p. 330 (Line 19) to 331 (Line 20). See also, quote in Section 2.3.1 of the main report.
[38] Olsen Deposition. 9/10/08. p. 274. (emphasis added).

analysis involved testing his PCA interpretation against purported independent ground-truth information (i.e. data not included in the actual PCA such as poultry house density data and the locations of waste water treatment plants).[39] In support of his poultry impact threshold (PC1>1.3) Olsen presented the following discussion, based on poultry-house density:

> *"The value* [the 1.3 PC1 threshold] *was selected by examining the locations and scores of samples, <u>particularly the scores of reference samples and samples in **low poultry house density** areas</u>. In summary, the samples with PC1 scores below approximately 1.3 include all samples from reference locations (six total), 9 out of 10 samples from <u>HFS30 (small watershed location with **low poultry house density**</u>) and 10 out of 11 samples from <u>HFS28A (small watershed with **low poultry house density**</u>). The one sample from HFS30 and the one sample from HFS28A with higher PC1 scores were collected during extreme flow events. Overall 441 of the 573 samples (77%) had PC1 scores higher* [than] *1.3 and show some poultry contamination."*[40]

Note that this discussion addresses <u>only five sampling locations</u> (2 high flow sampling stations in the watershed (HFS28A and HFS30) and 3 base-flow reference stream locations (six samples from three locations) outside the watershed). This constitutes 27 of 573 SW3 samples (<5%) collected from 5 of 175 sample locations (< 3%). Olsen's report makes no mention of samples that contradict his poultry impact threshold, so the clear implication is that this subset of the data is representative of Olsen's spatial analysis a whole. This is not the case, and much of the remainder of this report will focus on the numerous inconsistencies in Olsen's theory, as revealed by the spatial analysis.

The bottom-line illustration of Olsen's interpretation of SW3 with respect to his poultry impact interpretations was his Figure 6.11-23 (reproduced below as Figure 2-4). On that map, a green dot (●) indicates a SW3 surface water sample location with an average PC1 score less than 1.3. A red dot (●) indicates a SW3 surface water sample location with an average PC1 score greater than 1.3. As such red-dots on his figure represent "*poultry impacted*" samples (see legend on Figure 2-4). In deposition testimony, Olsen confirmed this, but included the caveat/qualifier that a red dot in this map indicates only that "*There's some poultry contamination. Nothing about dominance.*"[41] In other words, a sample classified by Olsen as "WWTP dominant" would plot on this map as a red-dot, because all samples in his "*WWTP Dominant Impact*" area exhibit PC1 scores greater than 1.3 (see Figure 2-3).

The 1.3 PC1 threshold and this map then led Olsen to conclude that "*78 percent of the locations sampled in the IRW show some poultry contamination. Locations with PC1 scores higher than 1.3 are shown in red; those with scores less than 1.3 are shown in green.*"[42] This is the basis of Olsen's flagship opinion coming out of his PCA: that "*Poultry waste is by far the dominant contamination source in the IRW when compared to other sources.*"[43] Clearly, the validity of this opinion is directly dependent on the validity of the 1.3 threshold, which in turn is dependent on the validity of Olsen's spatial analysis. As such, the spatial analysis deserves scrutiny that goes beyond the five sample locations discussed by Olsen in the above quote.

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[39] Olsen (2008a). p. 6-34: Steps 12 and 13.
[40] Olsen (2008a). p. 6-59 to 6-60. (emphasis added).
[41] Olsen Deposition (9/11/08). p. 339 (Lines 12-13).
[42] Olsen (2008a). p. 6-60. 2nd paragraph, as corrected by Olsen's errata (Olsen, 2008b – page 7).
[43] Olsen (2008a). p. 1-2. Bullet 3.

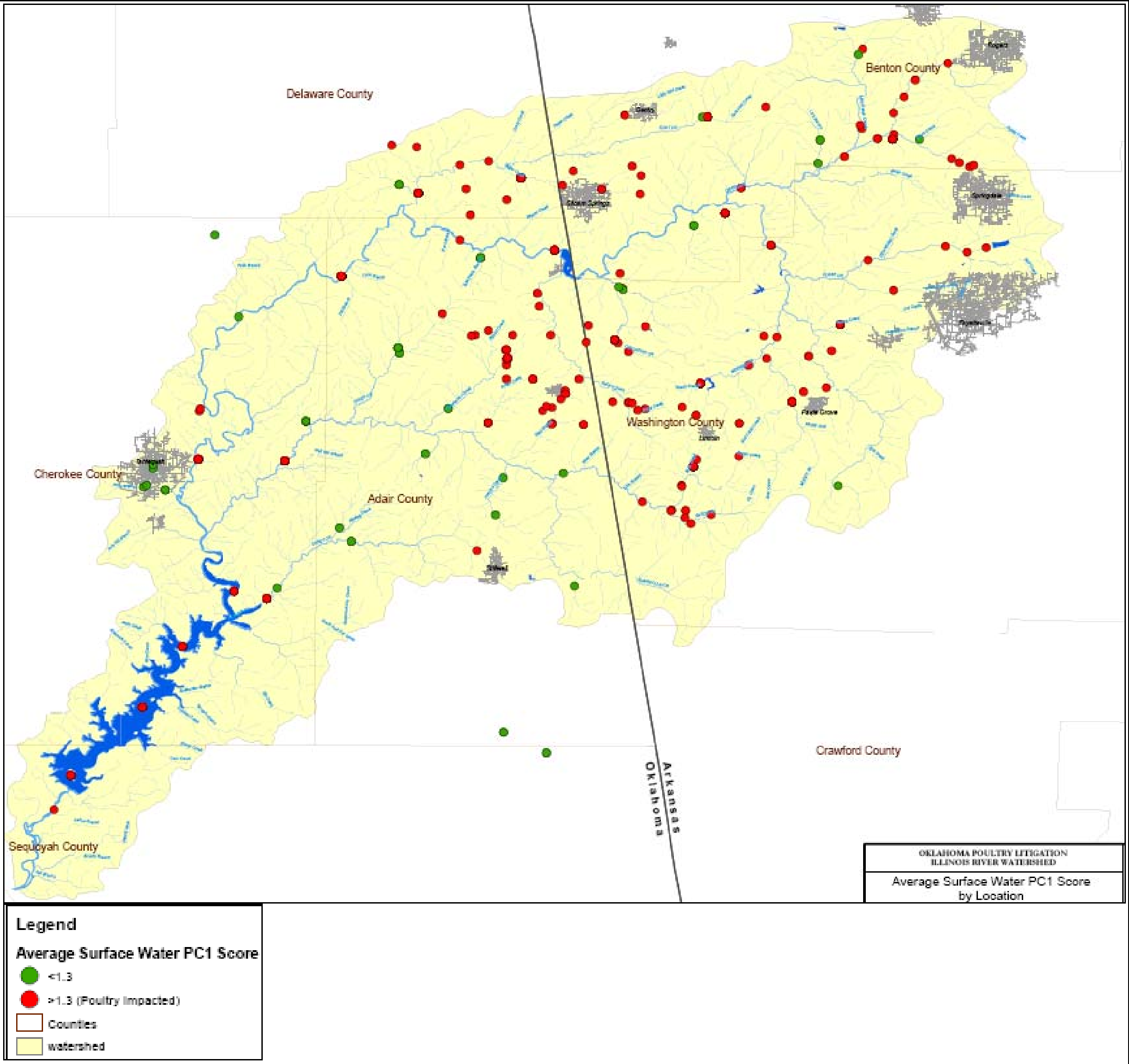


**Figure 2-4.** Olsen's red-dot / green-dot map showing average PC1 scores for PCA run SW3. This figure is direct copy of Olsen's Figure 6.11-23. On this map, if multiple samples were collected from a location, the average of all PC1 scores from that location was taken. All locations that exhibit an average PC1 score > 1.3 (using Olsen's PCA run SW3) are shown as red circles (●) and are classified as 'poultry-impacted' or so the legend indicates. Olsen admitted in deposition testimony that this is actually not true. This is discussed in more detail in Sections 3.1 and 3.2.

In Olsen's quote above, he points to data from only two high-flow sampling stations, both of which he claims (1) have average PC1 scores less than 1.3; and (2) are located in low poultry-house density subbasins within the IRW.[44] Figure 2-5 shows Olsen's average PC1 scores for <u>all</u> high-flow samples (including the two cited by his quote above: HFS28A and HFS30). On my map, I have plotted red-dots and green-dots based on Olsen's 1.3 PC1 threshold (just as Olsen did in his Figure 6.11-23 – Figure 2-4 above). However, my map is different from Olsen's Figure 6.11-23 in that (1) I have plotted only high-flow samples, and (2) I used Olsen's poultry house density data (rather than a generic yellow shaded area) as my basemap.

[44] Olsen (2008a). p. 6-60.

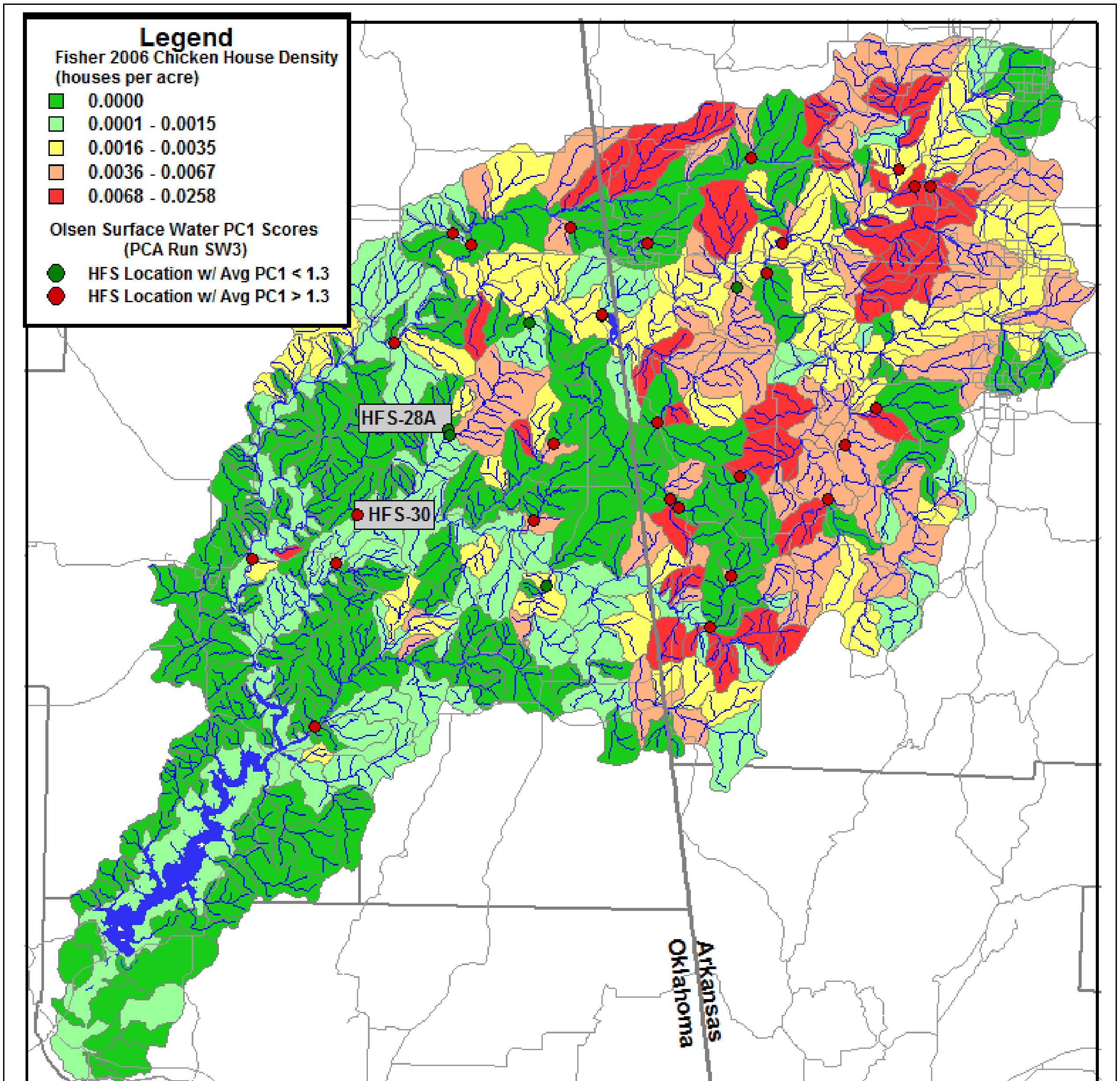


**Figure 2-5.** PC1 scores map for high-flow sample stations, plotted over Olsen's poultry house density data.

The two high-flow sample stations cited by Olsen in support of his 1.3 PC1 criterion (HFS-28A and HFS-30 - p. 6-60 of his report) are labeled. Poultry house data were produced as GIS shape files by Olsen in his production of materials relied-upon.

Having plotted PC1 scores over the data supposedly relied upon by Olsen for his spatial analysis, there are clearly problems with his interpretation. Both high-flow stations cited by Olsen in the quote above (HFS-28A and HFS-30) are located in low poultry-house density areas (just as Olsen said). HFS-28A plots as a green-dot within a low poultry-house density area (again, just as Olsen indicated). But HFS-30 is shown as a red-dot within a low poultry-house density area (i.e. HFS-30 had an average PC1 score > 1.3). This contradicts Olsen's statement in the quote above, and the HFS-30 data are not consistent with Olsen's assertion of a *conservative* 1.3 PC1 poultry-impact threshold. The seven high flow samples collected at HFS-30 yielded an average

PC1 score greater than 1.3 (1.3022) and by the criteria stated in Olsen's report, should have been shown on his figure as a red-dot, not a green-dot.[45]

The inconsistency in Olsen's spatial analysis is not limited to HFS-30. If we scan across the map above (Figure 2-5) we see many red-dots plotting in green sub-basins. Olsen's spatial analysis discussion in his report never acknowledges such samples that contradict his theory, only the two high-flow stations that supposedly support it. In subsequent deposition testimony, Olsen acknowledged that there were *"a few minor exceptions"* to his 1.3 criterion.[46] Through the course of his September 2008 deposition, Olsen eventually conceded that there were: (1) cow-pasture edge of field samples that had PC1 scores greater than 1.3 (2 locations); (2) cattle impacted springs that had PC1 scores greater than 1.3 (two locations); (3) waste-water treatment plant effluent samples that had PC1 scores > 1.3 (three locations); and (4) samples collected in Tahlequah, Oklahoma (an area of high human population density, but low poultry house density) that had PC1 scores > 1.3 (six samples from five locations). There are also major contradictions to Olsen's theory with regard to base-flow samples. These contradictions to Olsen's poultry impact criteria and his spatial analysis are explored in greater detail in Section 3.0.

### 2.3.2 SW17: Surface Water Plus Wells, Springs and Geoprobe Samples

PCA run SW17 included the same 573 sample, 26 variable data set used for SW3, plus 126 additional groundwater samples (17 geoprobes, 49 springs and 60 wells – Table 2-2). Geoprobe is a field method that allows collection of shallow groundwater using a direct push method.[47] Well samples represent generally deeper groundwater collected from existing groundwater wells.[48] Springs are surface water features, but were classified by Olsen as 'groundwater' because they are presumably fed, at least to some degree, by groundwater seeps.[49]

The addition of these samples brought the total number in SW17 to 699. The sample types, number of samples, number of variables, missing data criterion, and transformations used for this PCA run are shown on Table 2-2 below. Variables that had ≥10% missing data are shown in red text.

[45] This explains why in deposition testimony, Olsen changed the PC1 threshold from 1.3 (as indicated in his report) to 1.30226 (See Olsen Deposition 9/10/08. p. 218 (Lines 5-7) and p. 219 (Lines 13-18)). Apparently, Olsen not only believes that his PC1 threshold is not arbitrary, but that it is precise to the fifth decimal place.

[46] Olsen Deposition. 9/10/08. p. 274.

[47] Olsen (2008a). p. 6-17. Bullet 5.

[48] Olsen (2008a). p. 6-17. Bullet 6.

[49] Olsen (2008a). p. 6-17. Bullet 7.

**Table 2-2.** Summary of Olsen PCA Run SW17.

| **PCA Run SW17**<br>**699** Samples<br>**26** Variable<br>≤ **6** Missing Data Points Allowed Per Sample | EDA_Group | Sample Summary: Total Number of Water Samples Available in CDM Database, for this Group | Sample Summary: Number of Samples that Meet Missing Data Criterion | Variable Summary: EDA_Variable | Variable Summary: Number of Samples with Data Reported | Variable Summary: Percent Missing Data | Transformation Used for PCA |
|---|---|---|---|---|---|---|---|
| **SW17** | GW - Geoprobe | 19 | 17 | AL_T | 699 | 0% | Log10 |
| 0428_SW_17 | GW - Spring | 57 | 49 | ALKALINITY | 691 | 1% | Log10 |
| | GW - Well | 62 | 60 | AS_T | 695 | 1% | Log10 |
| **Surface** | SW - Edge of Field | 89 | 65 | BA_T | 699 | 0% | Log10 |
| **Water and** | SW - Lake - Tenkiller | 533 | 29 | CA_T | 699 | 0% | Log10 |
| **Groundwater** | SW - Stream - BFC | 960 | 88 | CL | 689 | 1% | Log10 |
| | SW - Stream - Forest | 2 | 0 | **COLIFORMS** | **537** | **23%** | Log10 |
| | SW - Stream - HFC | 152 | 20 | CU_T | 695 | 1% | Log10 |
| | SW - Stream - High Flow - BFC | 55 | 48 | **ECOLI** | **447** | **36%** | Log10 |
| | SW - Stream - High Flow - HFC | 240 | 177 | **ENTERO** | **527** | **25%** | Log10 |
| | SW - Stream - NA | 10 | 0 | FE_T | 699 | 0% | Log10 |
| | SW - Stream - PA - BFC | 12 | 0 | **FECAL** | **523** | **25%** | Log10 |
| | SW - Stream - PA - HFC | 22 | 0 | K_T | 699 | 0% | Log10 |
| | SW - Stream - Synoptic | 24 | 1 | MG_T | 699 | 0% | Log10 |
| | SW - Stream - USGS - BFC | 107 | 60 | MN_T | 699 | 0% | Log10 |
| | SW - Stream - USGS - HFC | 115 | 81 | NA_T | 699 | 0% | Log10 |
| | SW - Stream - WWTP | 4 | 4 | NI_T | 695 | 1% | Log10 |
| | **Total** | **2463** | **699** | NO2_NO3 | 690 | 1% | Log10 |
| | | | | P_SOL_REAC | 685 | 2% | Log10 |
| | | | | P_T | 697 | 0% | Log10 |
| | | | | P_TD | 698 | 0% | Log10 |
| | | | | SO4 | 689 | 1% | Log10 |
| | | | | TDS | 656 | 6% | Log10 |
| | | | | **TKN** | **631** | **10%** | Log10 |
| | | | | TOC | 677 | 3% | Log10 |
| | | | | ZN_T | 695 | 1% | Log10 |

Information from Olsen-produced spreadsheet '*PCA_Water_Runs_Table.xls*' attachment to 5/9/08 email from Chappell to Olsen.

Olsen reported the same types of results for SW17 as he did for SW3. Scree-plots and average eigenvalue criteria indicated five significant principal components, but like SW3 he looked only at the first 2 principal components, and cited the 50.1 percent of the variance accounted for (barely half) to justify that decision.[50] In terms of interpretation, Olsen reported that:

> "*A similar evaluation of PC1 scores was performed for the SW17 run as for the SW3 run where the <u>PC scores for reference samples and samples from locations in areas of low poultry house density</u> were evaluated. This resulted in determination that <u>the same threshold PC1 score could be used</u> to determine poultry waste impact (samples with <u>PC1 > 1.3</u>).*"[51]

Note in the first underlined portion of the quote, that Olsen cites a similar spatial analysis as he did for SW3, with respect to his poultry house density data. As indicated in the second and third underlined portions of the quote, that analysis led Olsen to conclude an identical poultry-impact threshold for SW17 (PC1 > 1.3).

Olsen then presented the groundwater equivalent of his red-dot green-dot map, showing the locations of samples with PC1 scores greater than 1.3. This map is reproduced below as Figure 2-6.

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[50] Olsen (2008a). pp. 6-50 to 6-52.

[51] Olsen (2008a). p. 6-61. 2nd Paragraph. Emphasis added.

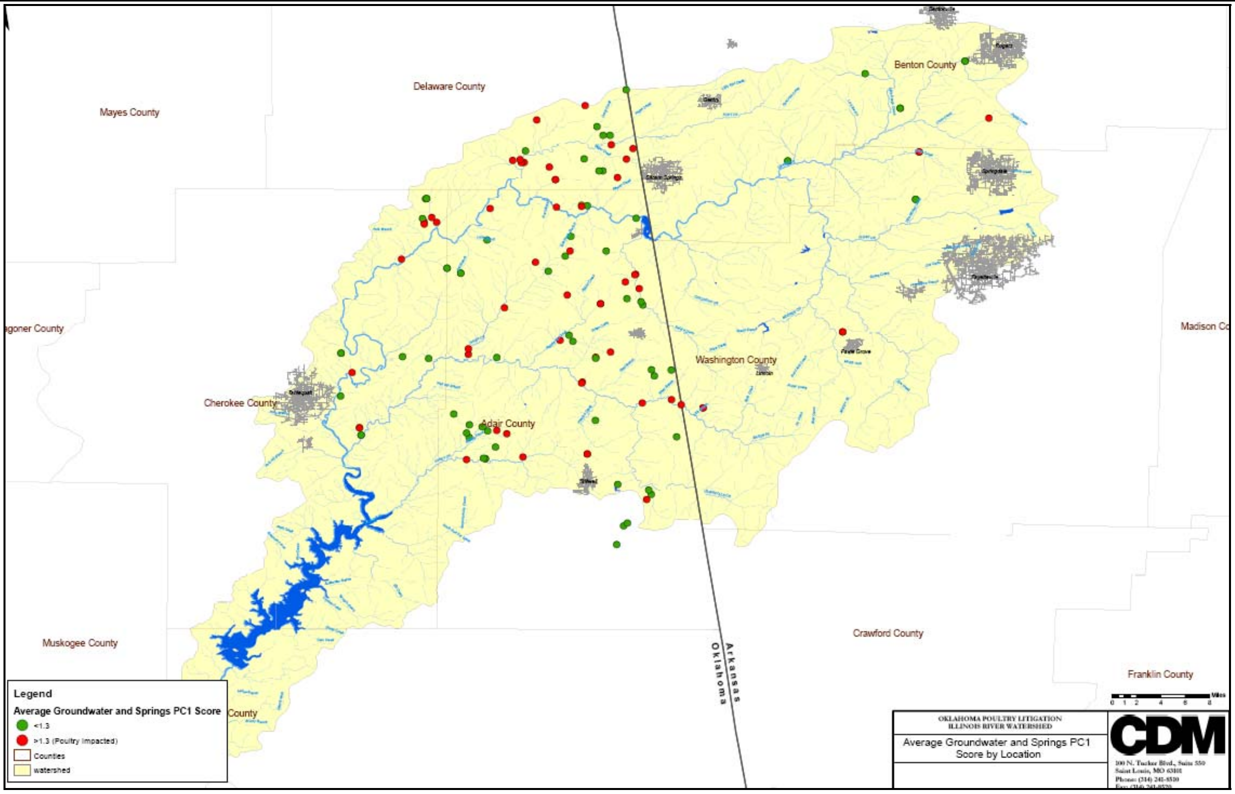



**Figure 2-6.** Direct copy of Olsen's Figure 6.11-24: average groundwater and spring PC1 scores.

Once again, Olsen showed his classification of groundwater on a generic base map. Figure 2-7, below, shows the same information plotted over Olsen's poultry house density data. Once again, there are numerous red-dots plotting in green areas and vice versa. Olsen addressed this inconsistency, at least in part, by pointing out that *"The three wells known to be greater than 150 ft in depth (actual depth = 203 to 803 ft) did not show poultry waste contamination."* These three wells were not identified by Olsen, and even if they were, it cannot explain all the inconsistencies observed here. Olsen's groundwater spatial analysis does not support his PC1>1.3 poultry impact classification.

Based on his 1.3 PC1 criterion, Olsen then reported that 51 of 112 locations on his groundwater red-dot / green-dot map (46%) plotted as red-dots.[52] By his criterion, less than half of the groundwater samples in the IRW are impacted by poultry litter. Even then, that number does not describe Olsen's presumed impact to homeowner wells, because domestic wells were just one of three categories of samples included as "*groundwater*." As indicated on Table 2-3 below (reproduced from the table on page 6-61 of Olsen's report) the percentage of homeowner wells that exhibit PC1 scores > 1.3 is only 40%.

[52] Olsen (2008a). p. 6-61. 2nd paragraph.

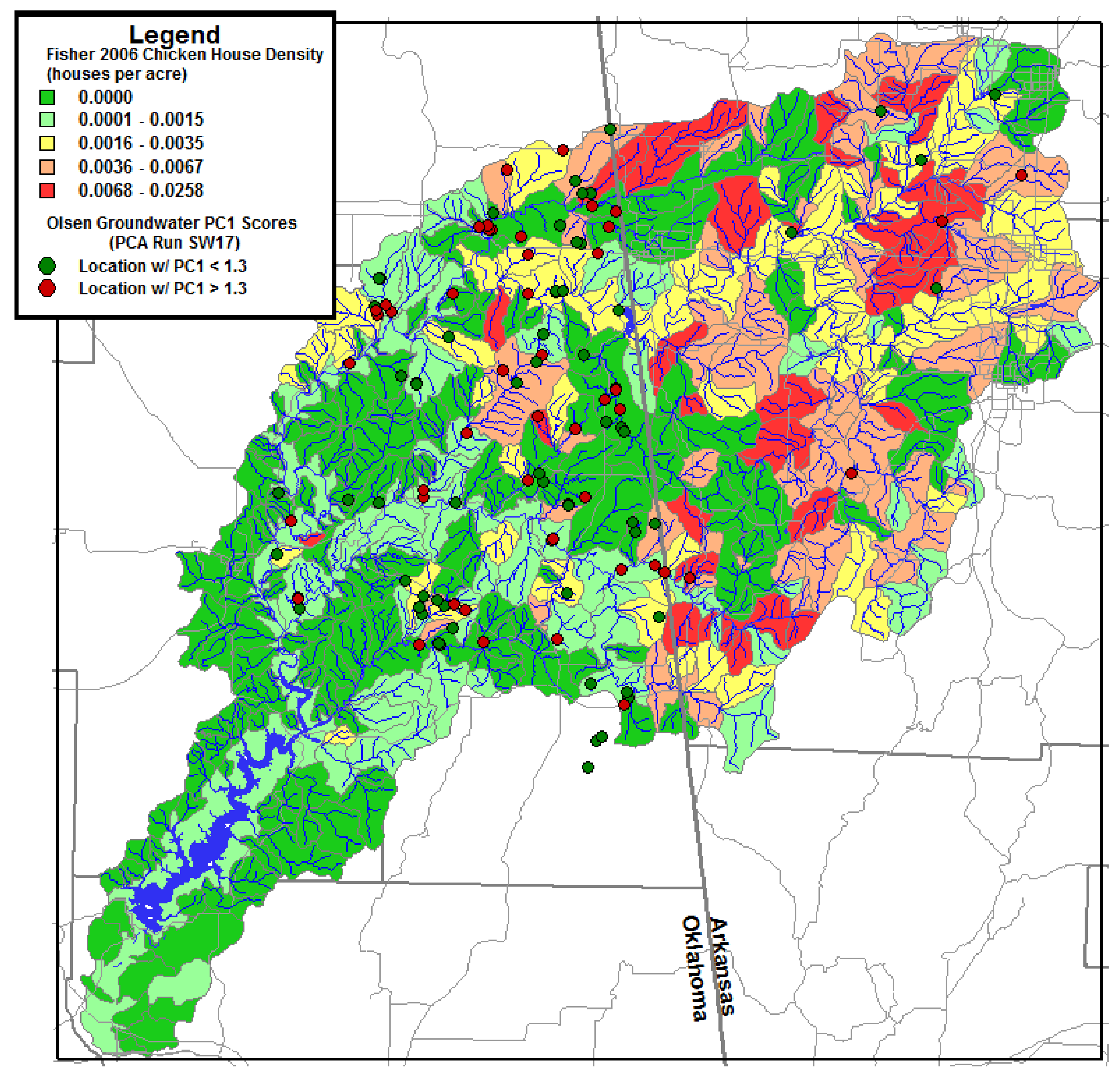



**Figure 2-7.** Olsen's red-dot/green-dot map for groundwater, plotted on poultry-house density map instead of generic base map.

**Table 2-3**. Sample Counts and Percentage of SW17 Groundwater Samples Exceeding Olsen's 1.3 PC1 Threshold

| Sample Type | Sample Counts | Percent > 1.3 |
|---|---|---|
| Geoprobe | 16/17 | 94 |
| Springs | 19/49 | 39 |
| Existing Wells | 24/60 | 40 |

**Reproduced from Olsen (2008a) p. 6-61**

Recall also that, according to Olsen, a PC1 score greater than 1.3 means only that there is some poultry-impact. It says nothing about dominance.[53] According to Olsen, in order to be classified as "*poultry-waste impact dominant*" a sample must exhibit a PC1 score > 1.3 and a PC2 score < 4.7 to 5.0.[54] Only 15 percent of groundwater wells meet this criterion (9 out of 60: Figure 2-8).

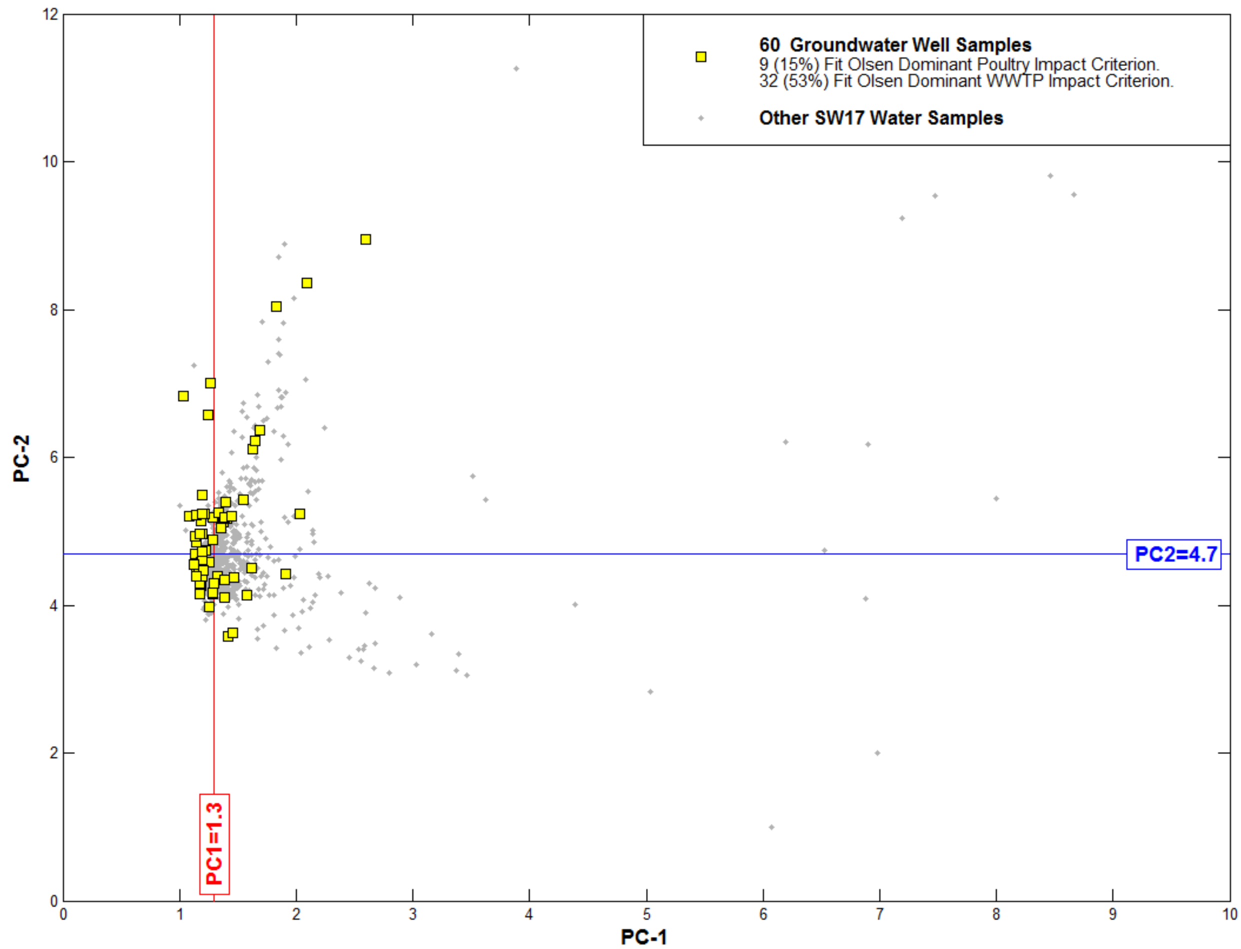



**Figure 2-8.** Scores plot for SW17 with groundwater samples (homeowner wells) highlighted.

Assuming that Olsen's PC1 and PC2 thresholds have any validity, groundwater is not nearly the poultry-impact problem that Olsen's claims for surface water. But once again the validity of Olsen's criteria is not supported by his spatial analysis. The locations of the nine well samples classified by Olsen's criteria as "*poultry-waste impact dominant*" are shown on Figure 2-9 with respect to Olsen's poultry-house density base map. The majority of these samples (six of nine) are located in areas of low poultry house density. Four plot in sub-basins that Olsen's map indicates have zero poultry-house density (dark-green). Two more plot within Olsen's second-lowest poultry house density classification (light-green). None of these nine samples plot within Olsen's maximum poultry-house density classification sub-basins (red).

[53] Olsen Deposition (9/11/08). p. 339 (Lines 12-13).
[54] Olsen Deposition (9/10/08). p. 279 (Lines 14-21).

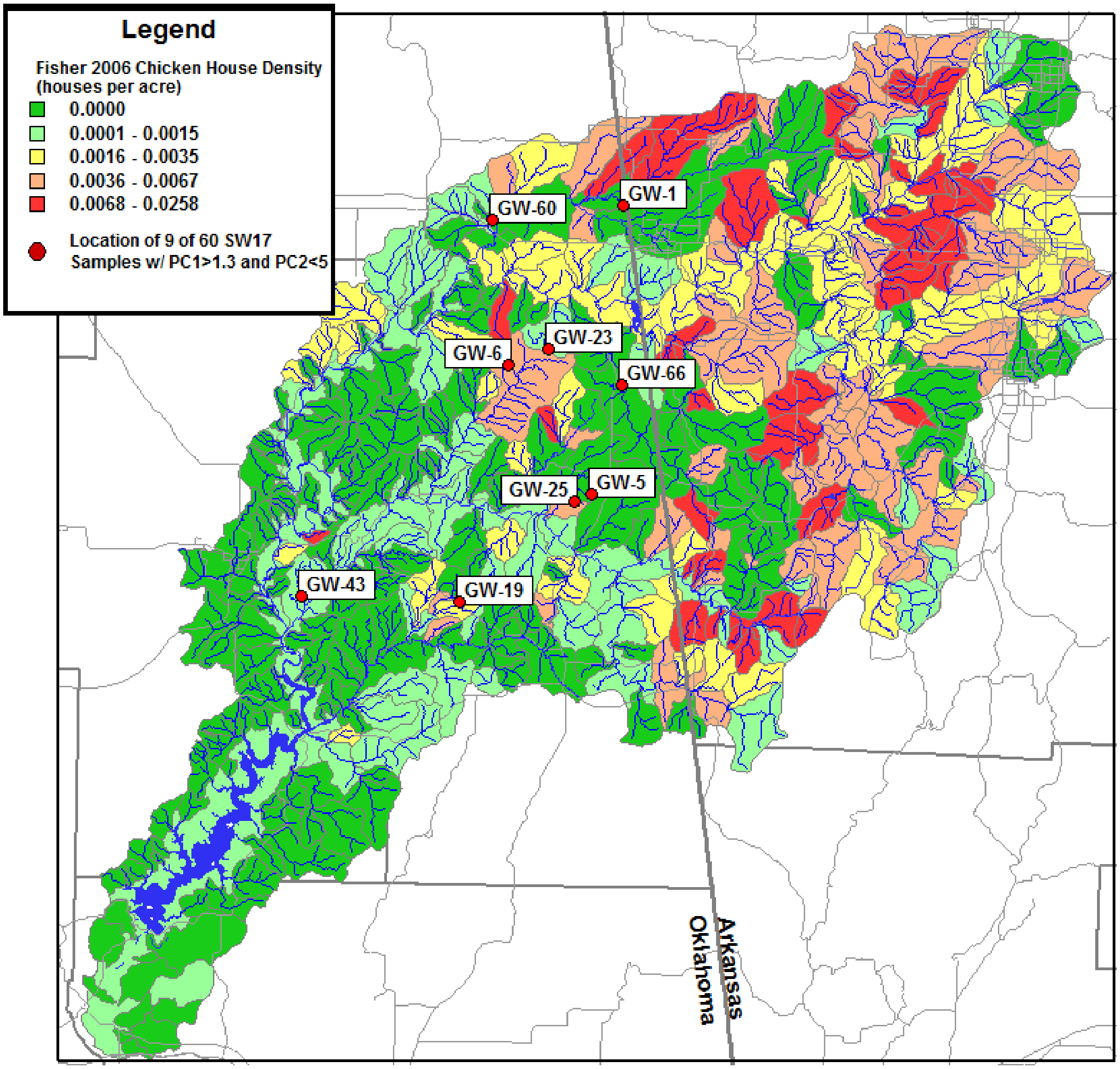



**Figure 2-9.** Locations of the nine (out of 60) SW17 groundwater wells classified by Olsen as "*poultry-waste impact dominant*"

**Note:** The majority of these nine samples plot in areas of low-poultry house density. Four plot in zero poultry house density sub-basins (dark-green). Two plot within the second lowest poultry house density classification of sub-basins (light-green). None plot in Olsen's maximum poultry-house density classification sub-basins (red).

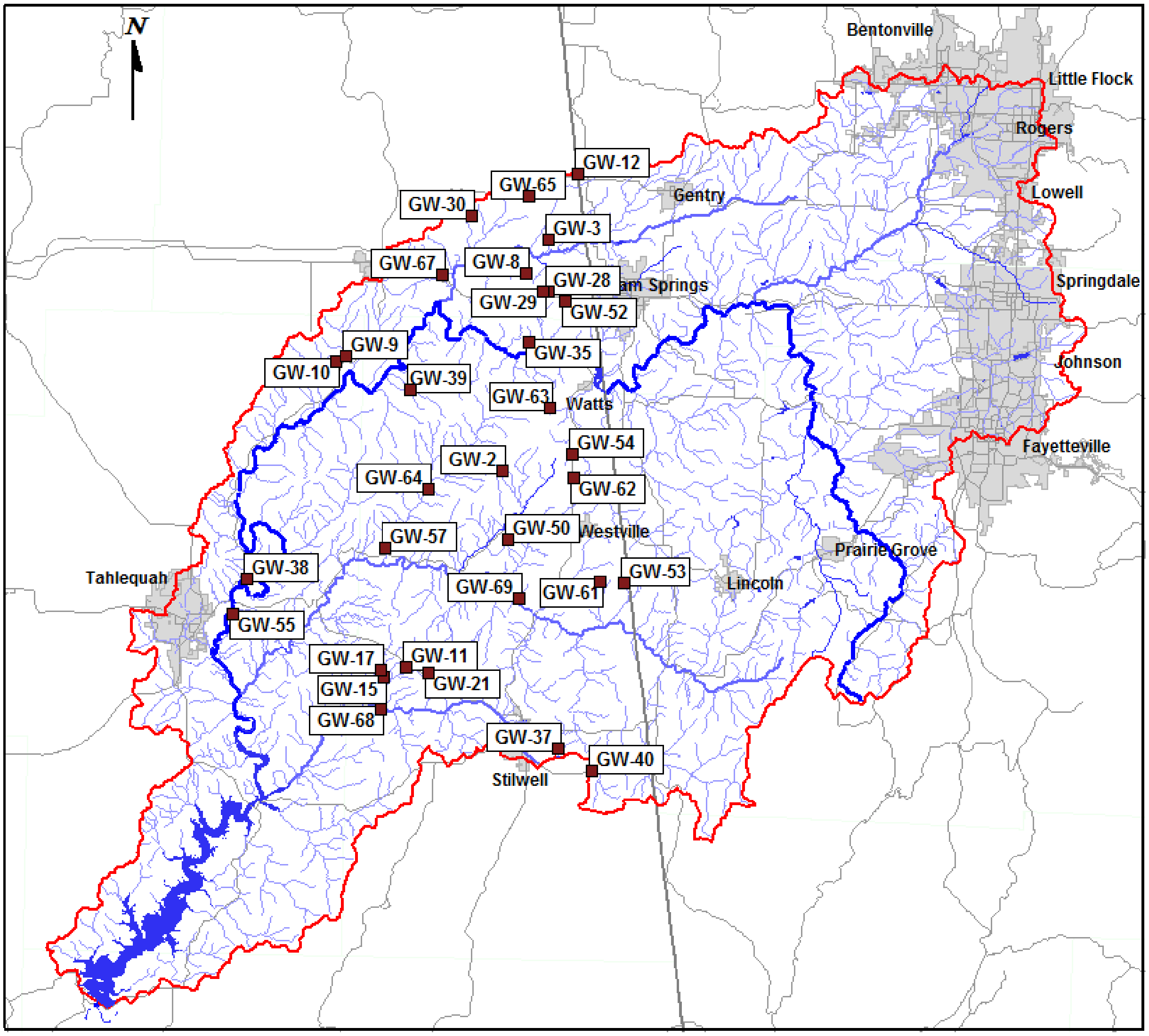
When Olsen discussed PC2 scores for SW17, he reported that:

> *"In addition to the samples showing poultry waste impact, some of the groundwater samples have higher PC2 scores than the typical samples identified as being impacted by poultry waste contamination (relatively lower PC2 scores). These groundwater samples potentially show human waste impact. Overall about 20 wells may show potential human impact."*[55]

In this quote, Olsen points to 20 groundwater samples that exhibit PC2 scores above his WWTP threshold of 4.7. In deposition he acknowledged that there were actually 29 SW17 samples with PC2 scores above his WWTP threshold. But even that number is wrong. There are actually 32 groundwater samples in Olsen's PCA run SW17 with PC2 scores greater than 4.7. As such, the number of wells that Olsen would classify as predominantly WWTP impacted is 32 of 60, or 53%. Olsen's WWTP criterion indicates that the majority of the wells sampled show evidence of WWTP impact. The locations of these wells are shown on Figure 2-10.

There is another important point within the above quote. Regardless of whether Olsen believes the number is 20, 29 or 32, his conclusion is that they "*potentially show human waste impact*." But Olsen's original interpretation of PC-2 was more much more specific than '*human waste.*' He identified PC2 as "*associated with WWTP effluent*."[56] The implication in Olsen's interpretation of data from groundwater wells is that he equates the chemical fingerprint of large-scale WWTP effluent with untreated and/or small-scale, domestically treated human waste (i.e. septic tanks). Olsen has apparently concluded that the chemical/biological signatures of treated WWTP effluent and septic tank inputs are identical, but he never discusses the basis of such an opinion.

[55] Olsen (2008a). p. 6-61. 4th paragraph.
[56] Olsen (2008a). p. 6-57. 3rd paragraph.




| Sample | Date | Owner | Address | PC2 Score |
|---|---|---|---|---|
| GW-02 | 7/07/06 | Collins | Westville, OK 74965 | 5.166 |
| GW-03 | 7/11/06 | Saunders | 55286 S. 706 Rd. Colcord, OK 74338 | 6.575 |
| GW-08 | 7/13/06 | Glenn | 56492 S. 700 Rd. Colcord, OK 74338 | 4.969 |
| GW-09 | 7/18/06 | Schwabe | 4053 Hwy 10 Kansas, OK 74347 | 5.400 |
| GW-10 | 7/18/06 | Schwabe | 4053 Hwy 10 Kansas, OK 74347 | 5.118 |
| GW-11 | 7/19/06 | Brown | Rt. 4 Box 2065 Stilwell, OK 74960 | 4.962 |
| GW-12 | 7/20/06 | Blagg | 50769 S 725 Rd. Colcord, OK 74338 | 5.189 |
| GW-15 | 7/20/06 | Welch | Rt. 4 Box 2375 Stilwell, OK | 6.826 |
| GW-17 | 7/20/06 | Peteet | PO Box 912 Stilwell, OK 74960 | 4.859 |
| GW-21 | 7/24/06 | Baird | Rt. 3 Box 825 Stilwell, OK 74960 | 5.244 |
| GW-28 | 7/26/06 | Millican | 6482 Pine Dr. Colcord, OK 74388 | 4.881 |
| GW-29 | 7/26/06 | Granderson | 57274 So. 711 Rd. Colcord, OK 74338 | 5.493 |
| GW-30 | 7/26/06 | Potter | 53290 So. 670 Rd. Colocord, OK 74338 | 5.232 |
| GW-35 | 8/10/06 | Hester | Rt 2 Box 375, Watts OK 74964-9513 | 7.010 |
| GW-37 | 8/10/06 | Rogers | Rt 2 Box 1751-A Stilwell, OK 74960 | 5.206 |
| GW-38 | 8/10/06 | Fite | Hwy 10, north of Hwy 62 intersection | 5.045 |

| Sample | Date | Owner | Address | PC2 Score |
|---|---|---|---|---|
| GW-39 | 8/10/06 | Oakball | Rt 1 P.O. Box 1038 | 4.741 |
| GW-40 | 8/15/06 | Faubian | Rt. 6 Box 1339, Stilwell, OK 74960 | 8.942 |
| GW-50 | 1/22/07 | Beaver | Rt. 2 Box 431, Westville, OK | 5.135 |
| GW-52 | 1/22/07 | Ames | 4795 Cedar Dr. W Siloam Springs (Colcord) | 6.116 |
| GW-53 | 1/22/07 | McCoy | RR1 Box 49 | 4.936 |
| GW-54 | 1/23/07 | Reese | Rt 1 Box 154 Watts, OK 74964 | 6.228 |
| GW-55 | 1/23/07 | McAlpine | 12979 S 543 Rd, Tahlequah, OK | 4.731 |
| GW-57 | 1/23/07 | Blagg | 50769 S 725 Rd. Colcord, OK 74338 | 8.358 |
| GW-61 | 7/11/07 | Choate | PO Box 897, Westville, OK | 5.215 |
| GW-62 | 7/11/07 | Scism | RR2 Box 567, Westville, OK | 5.229 |
| GW-63 | 7/10/07 | Dixon | Rt. 1 Box 450, Watts, OK 74964 | 5.242 |
| GW-64 | 6/28/07 | Kuelbs | Rt 2 Box 584, Westville, OK 74965 | 5.427 |
| GW-65 | 7/10/07 | Kustanborter | 21213 State Highway 116, Colcord, OK | 5.181 |
| GW-67 | 7/11/07 | Sewell | P.O. Box 16478 E 567 Rd, Del. County, OK | 8.035 |
| GW-68 | 7/10/07 | Turner | RR01 Box 1010, Stillwell, OK | 6.373 |
| GW-69 | 7/30/07 | Vance | Rt 2 Box 181, Westville, OK 74965 | 5.198 |

**Figure 2-10.** Locations, sample-dates and PC2 scores for 32 (out of 60) groundwater wells classified by Olsen as impacted by human waste.

### 2.3.3 SW22: Surface Water Plus Springs

SW22 was not included in Olsen's list of "*four major PCA runs*"[57] which he designated as such because they were "*the most important to the investigation or project objectives.*"[58] This is curious because SW22 forms the basis of Olsen's cattle manure impact argument, which would seem to be important to project objectives. As such, I have included it in this discussion. SW22 included the same 26 variables used in SW3 and SW17, but the samples differed. SW22 included all surface water samples included in SW3, as well as the 49 spring samples in SW17. Unlike SW17, SW22 did not include the geoprobe or groundwater well samples. This resulted in a data set with 622 samples and 26 variables. Sample types, number of samples, number of variables, missing data criterion, and transformations used for SW22 are shown on Table 2-4 below. Variables that had ≥10% missing data are shown in red text. Once again, a 2 principal component model was chosen by Olsen, which this time accounted for 55% of the variance.

**Table 2-4**. Summary of Olsen PCA Run SW17.

| **PCA Run SW22**<br>**622** Samples<br>**26** Variable<br>= **6** Missing Data Points Allowed Per Sample | | Sample Summary | | Variable Summary | | | Transformation Used for PCA |
|---|---|---|---|---|---|---|---|
| | EDA_Group | Total Number of Water Samples Available in CDM Database, for this Group | Number of Samples that Meet Missing Data Criterion | EDA_Variable | Number of Samples with Data Reported | Percent Missing Data | |
| **SW22** | GW - Spring | 57 | 49 | AL_T | 622 | 0% | Log10 |
| 0504_SW_22 | SW - Edge of Field | 89 | 65 | ALKALINITY | 614 | 1% | Log10 |
| | SW - Lake - Tenkiller | 533 | 29 | AS_T | 618 | 1% | Log10 |
| **Surface Water Plus Springs (No Other Groundwater Samples)** | SW - Stream - BFC | 960 | 88 | BA_T | 622 | 0% | Log10 |
| | SW - Stream - Forest | 2 | 0 | CA_T | 622 | 0% | Log10 |
| | SW - Stream - HFC | 152 | 20 | CL | 612 | 2% | Log10 |
| | SW - Stream - High Flow - BFC | 55 | 48 | **COLIFORMS** | **460** | **26%** | Log10 |
| | SW - Stream - High Flow - HFC | 240 | 177 | CU_T | 618 | 1% | Log10 |
| | SW - Stream - NA | 10 | 0 | **ECOLI** | **370** | **41%** | Log10 |
| | SW - Stream - PA - BFC | 12 | 0 | **ENTERO** | **450** | **28%** | Log10 |
| | SW - Stream - PA - HFC | 22 | 0 | FE_T | 622 | 0% | Log10 |
| | SW - Stream - Synoptic | 24 | 1 | **FECAL** | **446** | **28%** | Log10 |
| | SW - Stream - USGS - BFC | 107 | 60 | K_T | 622 | 0% | Log10 |
| | SW - Stream - USGS - HFC | 115 | 81 | MG_T | 622 | 0% | Log10 |
| | SW - Stream - WWTP | 4 | 4 | MN_T | 622 | 0% | Log10 |
| | **Total** | **2382** | **622** | NA_T | 622 | 0% | Log10 |
| | | | | NI_T | 618 | 1% | Log10 |
| | | | | NO2_NO3 | 613 | 1% | Log10 |
| | | | | P_SOL_REAC | 608 | 2% | Log10 |
| | | | | P_T | 620 | 0% | Log10 |
| | | | | P_TD | 621 | 0% | Log10 |
| | | | | SO4 | 612 | 2% | Log10 |
| | | | | TDS | 587 | 6% | Log10 |
| | | | | **TKN** | **554** | **11%** | Log10 |
| | | | | TOC | 600 | 4% | Log10 |
| | | | | ZN_T | 618 | 1% | Log10 |

Information from Olsen-produced spreadsheet '*PCA_Water_Runs_Table.xls*' as attachment to 5/9/08 email from Chappell to Olsen.

SW22 forms the basis of Olsen's cattle-manure impact argument on page 6-61 and 6-62 of his report, and that argument is reproduced below, in its entirety:

> ***"Evaluation of Potential Impact of Cattle Manure***
> *The potential impact due to cattle manure was previously discussed in Section 6.4.2. These mass balance calculations indicate that any impact or contamination from cattle manure would be small (< 10-15 percent) compared to the impact due to poultry waste disposal. Previous steps in this subsection (i.e. step 12 discussing waste characteristics) show that cattle manure and cattle manure*

[57] Olsen (2008a). p. 6-51. Last paragraph.
[58] Olsen p. 6-50. See also Table at the top of page 6-52.

> *leachate are very different in chemical composition when compared to poultry waste and poultry waste leachate. Therefore, if cattle waste provides a major impact on contamination in the IRW, a dominant signature should be observed in the PCA. To assist in this evaluation, samples with known cattle contamination were evaluated. The chemical and bacterial compositions of these samples have been previously provided in* ***Tables 6.11-10 and 6.4-2a).*** *The four samples documented with cattle contamination are: SPR-LAL16-SP2, SPR-26, EOF-CP-1B and EOF-CP-1A.* ***Figure 6.11-25*** *shows the PC1 vs PC2 score plot for PCA run SW22 (surface water and springs). Also shown on this figure are the locations of the four samples with potential cattle contamination. Two of the samples (the springs) plot in the WWTP impact area while the other two samples plot on the edge of the poultry waste impacted area. These four samples have very different PC scores and no consistent relation or group is observed in the PCA. If cattle contamination contributed a significant impact to contamination in the IRW, a clear signature and associated group should be observed in the PCA and the four samples with cattle contamination would be in the group. Based on the mass balance calculations, the comparison of chemical composition and the PCA analyses, cattle waste is not a major source of chemical contamination in the IRW."*[59]

Olsen did not show loading bar-graphs, coefficient bar graphs or scree plots for this PCA run, but he did produce a single scores plot (referenced in the quote above and reproduced below as Figure 2-11).

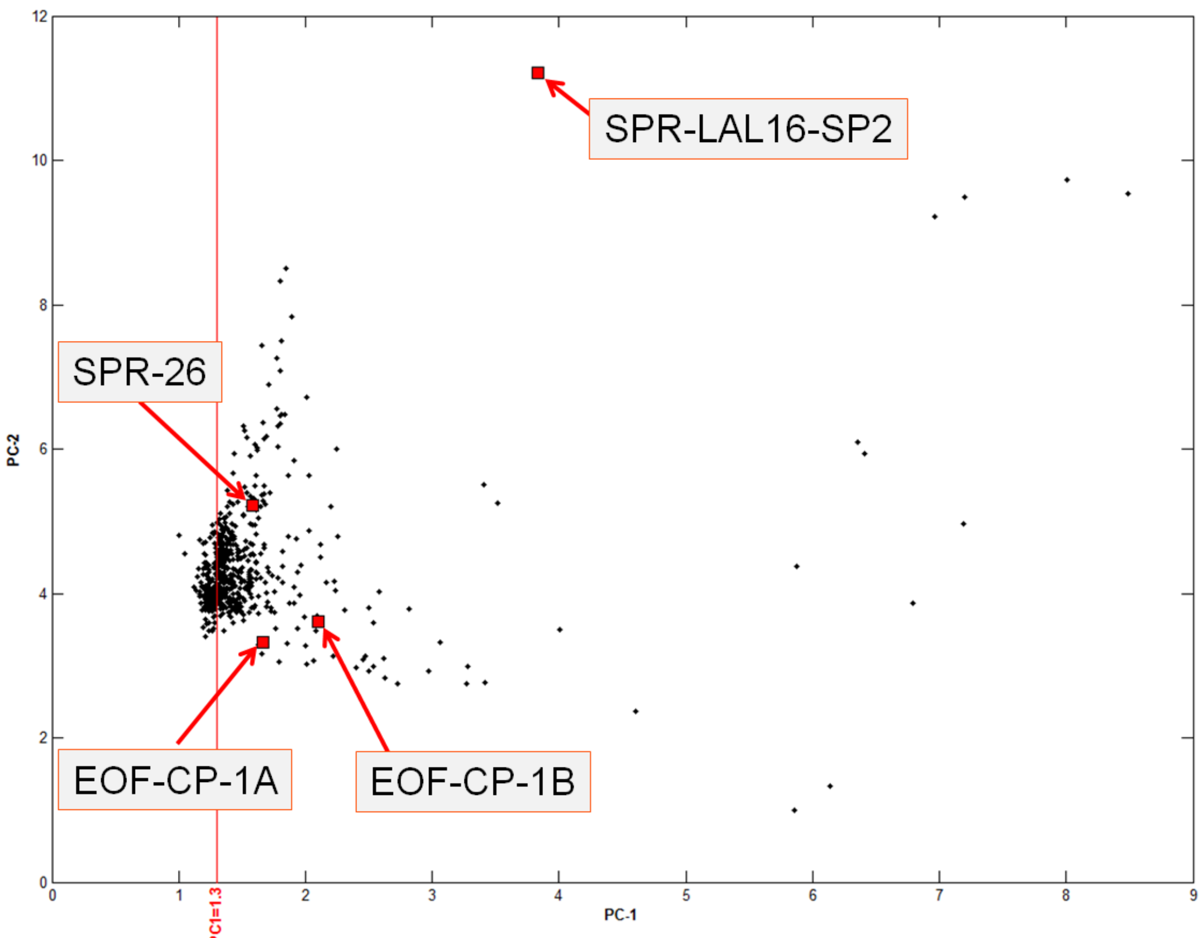



**Figure 2-11.** SW22 scores plot: Samples with known cattle contamination plotted as red squares. Reproduction of Olsen Figure 6.11-25. Annotation of sample -names for Olsen's four cattle-impacted samples, and Olsen's PC1 poultry-impact threshold (1.3) have been added. The sample shown as SPR-26 is actually the average scores from two individual samples (See Section 3.3.2).

[59] Olsen (2008). p. 6-61 to 6-62. Emphasis added.

On this graph, the "*four samples documented with cattle contamination*"[60] are plotted as red squares. All other SW22 samples are plotted as black dots. The four cattle impacted samples plot across a wide area of the scores plot, and it is this range of variation that is the basis of Olsen's argument, quoted above. There are major problems with this argument, and they will be discussed in detail in Section 3.3 of this report. But two of the most important problems are summarized here. First, note that all four of Olsen's "*samples documented with cattle contamination*"[61] exhibit PC1 scores greater than 1.3. Second, two of the four cattle impacted samples were edge-of-field samples collected from cow pastures (EOF-CP) where poultry litter had never been applied.[62] Unlike the spring samples (SPR), these two EOF-CP samples were included in SW3 (the PCA run that formed the basis of Olsen's poultry-impact arguments). If we highlight the EOF-CP samples on Olsen's SW3 scores plot, we see that both plot within Olsen's "*poultry-waste dominant impact*" area (Figure 2-12).

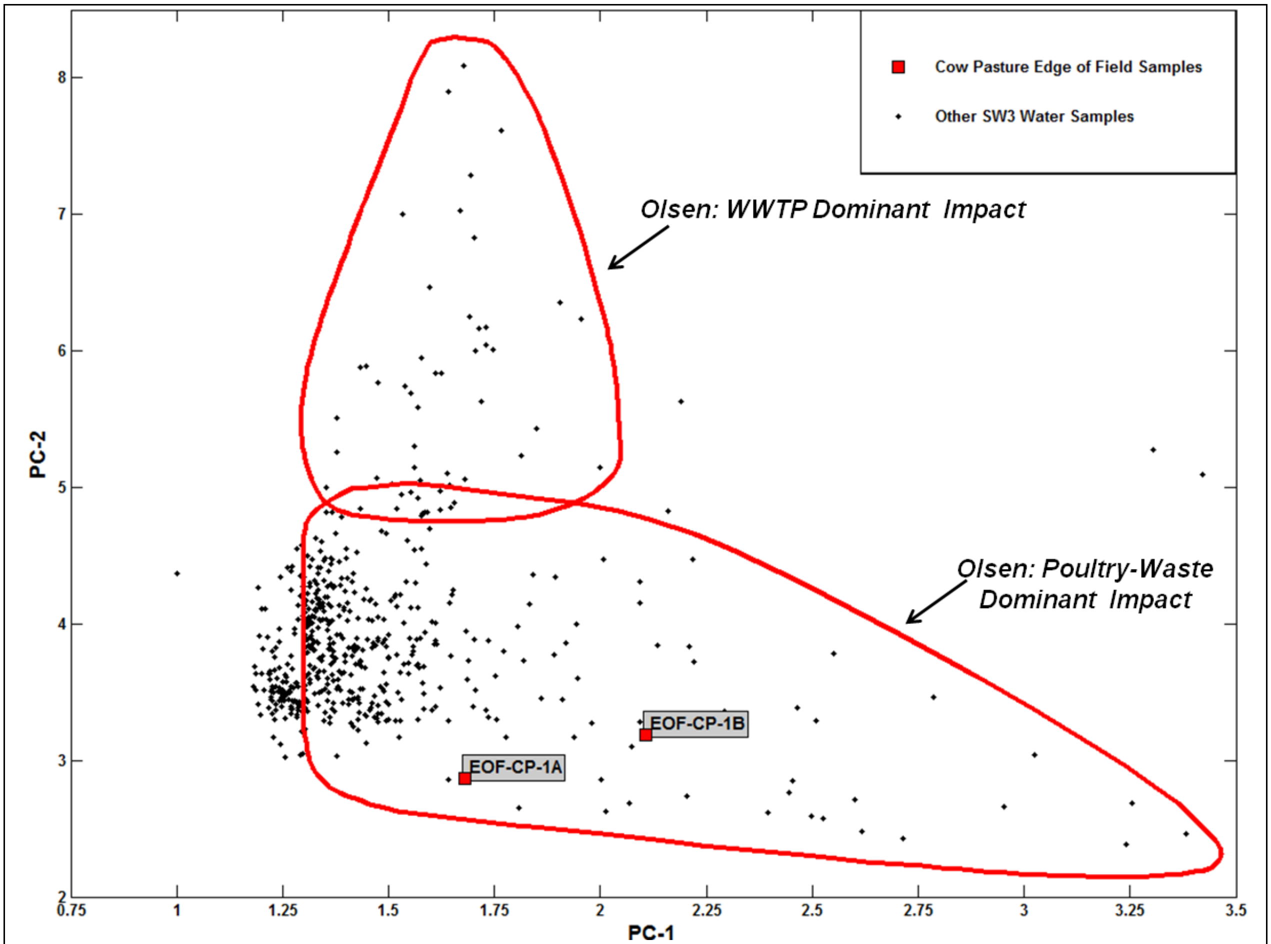



**Figure 2-12.** SW3 scores plot with cattle impacted edge-of-field samples highlighted.

[60] Olsen (2008a). p. 6-62 (line 5).
[61] Olsen (2008a). p. 6-62. Lines 4-6.
[62] See Field CDM/Lithochimea field notes from March 31, 2008 (STOK005374).

If one wishes to successfully challenge Olsen's criteria for a "*unique poultry waste signature*" they need look no further than this figure. This contradiction to Olsen's theory was never disclosed in his report. In addition, one could not see it for themselves on his score plots, because he did not use a unique symbol for EOF-CP samples. Rather, Olsen showed EOF-CP samples on his SW3 score plots using the same symbol shape and color used for all other EOF samples.[63]

In Olsen's discussion of SW22 in his report, he never disclosed that all four cattle impacted samples exhibited scores greater than 1.3, or that two of them plot squarely within his *poultry-waste dominant impact* area. As discussed in Section 3.3 of this report, these omissions were not because he failed to recognize these contradictions, or their significance. Section 3.3 will provide a detailed review of Olsen's cattle impact argument, as well as a summary of how that argument evolved from the February 2008 PI hearing, to the subsequent collection of the cow-pasture edge of field samples in March 2008, to his May 14 expert report, and ultimately to his September 2008 deposition testimony.

### *2.3.4 SD1: Solids (Manure, Litter, Soils, Sediment – No Cores)*

Olsen's PCA run SD1 included 32 variables measured in 203[64] solids samples. Solids samples were from three major groups: soil/sediment; cattle manure, and poultry litter. The soil/sediment group was comprised of surface soils, Lake Tenkiller sediments (grab samples only – no core samples), small reservoir sediments and stream sediment. Up to 6 missing data points were allowed per sample. The sample types, number of samples, number of variables, missing data criterion, and transformations used for this PCA run are shown on Table 2-5 below. Variables that had ≥10% missing data are shown in red text.

[63] See Olsen (2008a) Figures 6.11-18c; 6.11-18d; and 6.11-18e

[64] Olsen reported that SD1 had 203 samples but the results file produced for this run ('Results_Solids_0501_SD_1.xls') reported scores for only 202 samples. See Olsen (2008a - Table 6.11-7b). The missing sample appears to be a poultry litter sample. Olsen does not explain the reason for this discrepancy.

**Table 2-5.** Summary of Olsen PCA Run SD1.

| PCA Run SD1<br>203 Samples<br>32 Variable<br>= 6 Missing Data Points Allowed Per Sample | | Sample Summary | | Variable Summary | | | Transformation Used for PCA |
|---|---|---|---|---|---|---|---|
| | EDA_Group | Total Number of Solids Samples Available in CDM Database, for this Group | Number of Samples that Meet Missing Data Criterion | EDA_Variable | Number of Samples with Data Reported | Percent Missing Data | |
| SD1<br>0502_SD_1<br><br>Solids Analysis | SD - Cow Manuare | 10 | 10 | AL_T | 203 | 0% | Log10 |
| | SD - Litter | 20 | 19 | AS_T | 203 | 0% | Log10 |
| | SD - Litter - Plus Soil | 1 | 1 | BA_T | 203 | 0% | Log10 |
| | SD - Sediment - Lake - Small IRW Reservoirs | 12 | 12 | BE_T | 203 | 0% | Log10 |
| | SD - Sediment - Lake - Tenkiller - Grab | 15 | 15 | CA_T | 203 | 0% | Log10 |
| | SD - Sediment - Stream | 125 | 77 | CO_T | 203 | 0% | Log10 |
| | SD - Soil - Surface | 86 | 69 | **COLIFORMS** | **179** | **12%** | Log10 |
| | **Total** | **269** | **203** | CR_T | 203 | 0% | Log10 |
| | | | | CU_T | 203 | 0% | Log10 |
| | | | | **ECOLI** | **113** | **44%** | Log10 |
| | | | | **ENTERO** | **120** | **41%** | Log10 |
| | | | | FE_T | 203 | 0% | Log10 |
| | | | | **FECAL** | **155** | **24%** | Log10 |
| | | | | HG_T | 203 | 0% | Log10 |
| | | | | K_T | 203 | 0% | Log10 |
| | | | | MG_T | 203 | 0% | Log10 |
| | | | | MN_T | 203 | 0% | Log10 |
| | | | | NA_T | 203 | 0% | Log10 |
| | | | | **NH4_WS** | **157** | **23%** | Log10 |
| | | | | NI_T | 203 | 0% | Log10 |
| | | | | NITROGEN | 203 | 0% | Log10 |
| | | | | OM | 198 | 2% | Log10 |
| | | | | **P_MEHLICH** | **167** | **18%** | Log10 |
| | | | | P_T | 202 | 0% | Log10 |
| | | | | **P_WS** | **181** | **11%** | Log10 |
| | | | | PB_T | 203 | 0% | Log10 |
| | | | | PH | 195 | 4% | None |
| | | | | SALTS | 203 | 0% | Log10 |
| | | | | **SO4_WS** | **157** | **23%** | Log10 |
| | | | | **STAPH** | **179** | **12%** | Log10 |
| | | | | V_T | 203 | 0% | Log10 |
| | | | | ZN_T | 203 | 0% | Log10 |

Information from Olsen-produced spreadsheet '*PCA_Solids_Runs_Table.xls*' as attachment to 5/9/08 email from Chappell to Olsen.

Once again, a 2 principal component model was chosen, accounting for 55% of the variance.[65] He presents 2 PC score plots for SD1 in Figures 6.11-20a through 6.11-20f. One of those (Figure 6.11-20c) is presented below as Figure 2-13

[65] Olsen (2008a). p. 6-52. Table at top of page

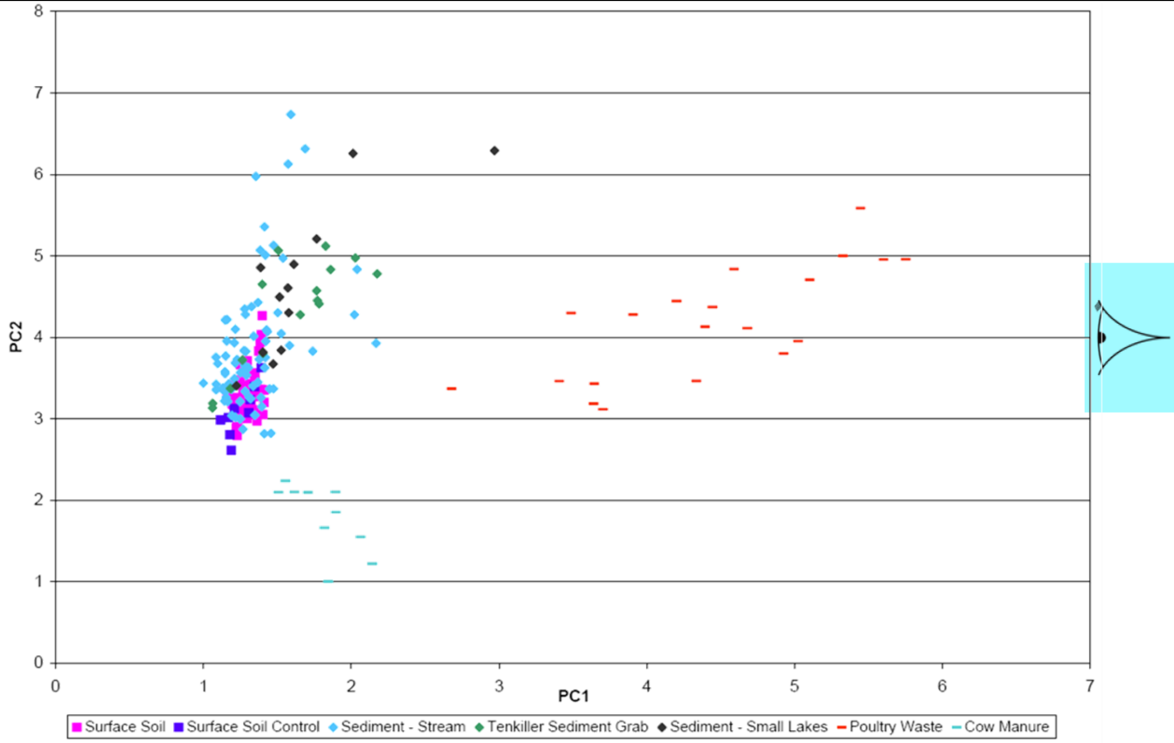



**Figure 2-13.** Direct copy of Olsen's Figure 6.11-20c: SD1 scores plot – varimax rotation. Eye symbol on the right has been added, and shows viewer's perspective for Figure 2-14.

The primary conclusion drawn from this plot was that cow manure samples plot separately from the poultry litter samples:

> *"cattle manure plots on the figure in a distinctly different group than the poultry waste. These two groups are most clearly separated using the varimax rotation. However, the separate groups are also observed on the PC1 vs PC2 figure using no rotation (Figure 6.11-20f). These figures show that cattle manure and poultry waste have distinct chemical/bacterial signatures."* [66]

On this plot, we see that there is separation between cattle manure (blue dashes), poultry litter (red dashes) and soil/sediment (all other symbols). But, one of the basic aspects of interpreting a scores plot is that samples that plot close together have similar chemical composition. Those that plot farther away have different chemical compositions. Given that, note that soil/sediment samples generally plot closer to cattle manure then they do to poultry litter. Olsen's PCA plot shown above suggest that soil and sediments are more similar in composition to cattle manure than poultry litter, but he never acknowledges this. But, for the first and only time in his report, he called on the scores from a third principal component in his discussion of this PCA run.

Figure 2-14 is a direct copy of Figure 6.11-20e from Olsen's report. In contrast to the PC1 vs PC2 graphs (Figure 2-13) the red-dashes (poultry litter) plot directly on top of the soil/sediment samples, and both appear to be separated from the cow manure samples (blue dashes).

[66] Olsen (2008a). p. 6-56. 2nd paragraph

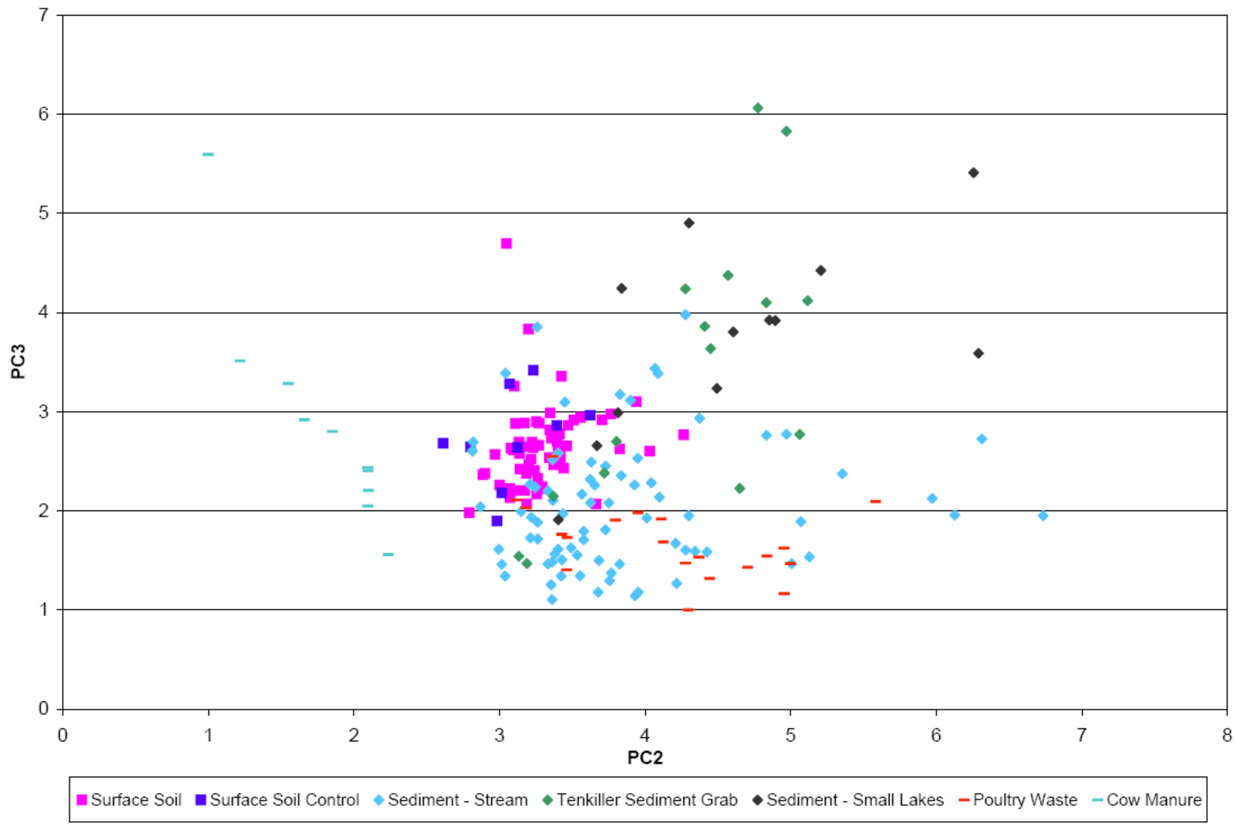



**Figure 2-14.** Direct copy of Olsen's Figure 6.11-20e. SD1 PC2 vs. PC3 scores plot .

Pointing to this second graph, Olsen makes the point that:

> *"cattle waste is distinct from the soils, and sediment samples. The poultry waste samples are closely related [to] the soil and sediment samples."*[67]

Olsen's statement is misleading, and demonstrates a basic lack of understanding of PCA. Figure 2-14 shows the same PCA results as Figure 2-13. Nothing has changed with respect to distance and separation of poultry litter samples compared to other samples. The only thing that has changed is our angle of view. In Figure 2-14 we are looking at the data from the perspective of the eye symbol that I added to the right side of Figure 2-13. In the second view (Figure 2-14) we are just looking down the barrel of PC1. That allows us to see where samples plot across a different 2-dimensional slice (PC2 vs PC3). We can no longer see the separation along the PC1 axis, but that separation did not suddenly vanish. On Figure 2-14, the poultry litter samples appear to overlap sediment/soil samples, but that is only because we can't tell how close the symbols are to our eye.

Olsen's argument is like holding your thumb in front of your face, directly in the line of sight between your eyes and the moon, and concluding that because your thumb and the moon overlap in your field-of-view, your thumb must be closer to the moon than it is to the tree 20 feet to your left. At best, Olsen's argument demonstrates a fundamental lack of understanding of PCA. At worst, he is fully aware that poultry litter samples are not closer to soil/sediments on the second figure, in which case he is purposely deceiving the reader.

[67] Olsen (2008a). p. 6-62. 2nd paragraph.

### 2.3.5 SD6: Solids (Manure, Litter, Soils, Sediment – Including Cores)

Olsen's final "*major PCA run*" was solids-run SD6. This PCA run included all samples in SD1, along with samples from sediment cores collected from Lake Tenkiller. Six cores were collected in Lake Tenkiller, but one was discarded (see Olsen report – Figure 2.12-1). As such, this PCA run differs from SD1 in that it includes an additional 88 sediment samples collected from 5 cores. Olsen indicates that this is the only difference, but as seen in Table 2-6, it also differs in that it included just 23 variables (rather than 32 variables in SD1). Nine variables missing in more than 10% of the SD1 samples have been removed from SD6. Up to 5 missing data points were allowed per sample, and Olsen's final SD6 data set had 299 samples and 23 variables.

**Table 2-6**. Summary of Olsen PCA Run SD6.

| **PCA Run SD6**<br>**299** Samples<br>**23** Variable<br>≤ **5** Missing Data Points Allowed Per Sample | **EDA_Group** | **Sample Summary**<br>**Total Number of Solids Samples Available in CDM Database, for this Group** | **Number of Samples that Meet Missing Data Criterion** | **EDA_Variable** | **Number of Samples with Data Reported** | **Percent Missing Data** | **Transformation Used for PCA** |
|---|---|---|---|---|---|---|---|
| **SD6** | SD - Cow Manuare | 10 | 10 | AL_T | 299 | 0% | Log10 |
| 0501_SD_6 | SD - Litter | 19 | 19 | AS_T | 299 | 0% | Log10 |
| | SD - Litter - Plus Soil | 1 | 1 | BA_T | 299 | 0% | Log10 |
| **Solids** | SD - Sediment - Lake - Small IRW Reservoirs | 12 | 12 | BE_T | 299 | 0% | Log10 |
| **Analysis** | SD - Sediment - Lake - Tenkiller - Core | 88 | 88 | CA_T | 299 | 0% | Log10 |
| | SD - Sediment - Lake - Tenkiller - Grab | 15 | 15 | CO_T | 299 | 0% | Log10 |
| **Core Samples** | SD - Sediment - Stream | 121 | 85 | CR_T | 299 | 0% | Log10 |
| **Added** | SD - Soil - Surface | 85 | 69 | CU_T | 299 | 0% | Log10 |
| | **Total** | **351** | **299** | FE_T | 299 | 0% | Log10 |
| | | | | HG_T | 299 | 0% | Log10 |
| | | | | K_T | 299 | 0% | Log10 |
| **Reduced** | | | | MG_T | 299 | 0% | Log10 |
| **Analyte List:** | | | | MN_T | 299 | 0% | Log10 |
| **Analytes** | | | | NA_T | 299 | 0% | Log10 |
| **Missing in >** | | | | NI_T | 299 | 0% | Log10 |
| **10% of** | | | | NITROGEN | 294 | 2% | Log10 |
| **Samples** | | | | OM | 288 | 4% | Log10 |
| **Removed** | | | | P_T | 298 | 0% | Log10 |
| | | | | PB_T | 299 | 0% | Log10 |
| | | | | PH | 282 | 6% | None |
| | | | | SALTS | 290 | 3% | Log10 |
| | | | | V_T | 299 | 0% | Log10 |
| | | | | ZN_T | 299 | 0% | Log10 |

Information from Olsen-produced spreadsheet '*PCA_Solids_Runs_Table.xls*' as attachment to 5/9/08 email from Chappell to Olsen.

Olsen's discussion of SD6 is a single, short paragraph.[68] He reports that Lake Tenkiller cores show a general decrease in PC2 scores from shallow to deep, but beyond that statement, he presents no conclusions or opinions based on this analysis. Rather, he just repeats the opinions of Bert Fisher, as paraphrased earlier in his report. Given that no new opinions are presented in context of SD6, it is not clear why Olsen designated SD6 as one of four "*major PCA runs*."

[68] Olsen (2008a). p. 6-62. 3rd paragraph.

# 3.0 Major Contradictions to Olsen's Interpretations

If we ignore problems of Olsen's methods, assumptions and implementation, and accept his PCA results at face value, there are major problems with his interpretation. Some of these were discussed briefly in Section 2.3, as part of my summary of Olsen's major PCA runs. In Section 2.3, I presented several examples where the purported ground-truth data and spatial-analysis that Olsen claimed to have used to evaluate the efficacy of his opinion conflict with his theory of a *unique poultry waste signature* based on PC1 scores greater than 1.3. In this section I will review these conflicts in more detail and will show that in each case, Olsen either concealed conflicting information from the reader and/or presented a convoluted explanation, based on speculation, in order to explain it away. These contradictions are not evident in Olsen's report because he was selective in the examples presented and cited only a few instances that supported his theory.

## 3.1 Tahlequah

As part of my evaluation of Olsen's PCA methodology, I reproduced SW3, and re-plotted his red-dot green-dot map. Reproduction of that figure, using my calculated PCA scores is shown below as Figure 3-1. Note on this figure that there are five sample locations within Tahlequah, Oklahoma. All five show an average PC1 score greater than Olsen's 1.3 poultry-impact threshold. But Tahlequah is an area of low poultry house density.[69] In Tahlequah, Olsen's spatial analysis does not support his theory.

Comparing my map (Figure 3-1) to Olsen's red-dot green-dot map (Figure 6.11-23 of his report – reproduced as Figure 2-4 above) shows that he plotted these same Tahlequah samples as green-dots. Olsen's map is wrong, as is shown on the table below. The scores on Table 3-1 were taken directly from Olsen's Appendix F, and show the PC-1 scores for six Tahlequah samples in PCA run SW3.[70] All six had scores greater than 1.3. They should have been plotted as red-dots on Olsen's map.

**Table 3-1**. SW3 PC Scores for Tahlequah Samples

| SW 3 Principal Component Scores | PC Size (No Rotation) normalized to 1 | |
|---|---|---|
| EDA_Sample | PC 1 | PC 2 |
| RBS-0000574:8/10/2006:SW:S:0:- | 1.4882282937 | 4.0293605941 |
| RBS-0000577:8/10/2006:SW:S:0:- | 1.4424297706 | 4.1783520334 |
| RBS-0000578:8/10/2006:SW:S:0:- | 1.3581186422 | 4.0013116585 |
| RBS-0000625:8/10/2006:SW:S:0:- | 1.3229373421 | 3.8085145848 |
| RBS-0000630:8/11/2006:SW:S:0:- | 1.6215165533 | 3.5363092996 |
| RS-578:5/2/2007:SW:S:0:- | 1.3022140797 | 3.8250842056 |

**Data from Olsen (2008a): Appendix F.**

[69] See Olsen Figure 2.5-1 as well as Figures 2-5 and 2-7 of this report.

[70] There were two sample from station 578, so in accordance with Olsen's method description, the average of those two samples' PC1 scores is shown as one of the five Tahlequah locations on the above map.

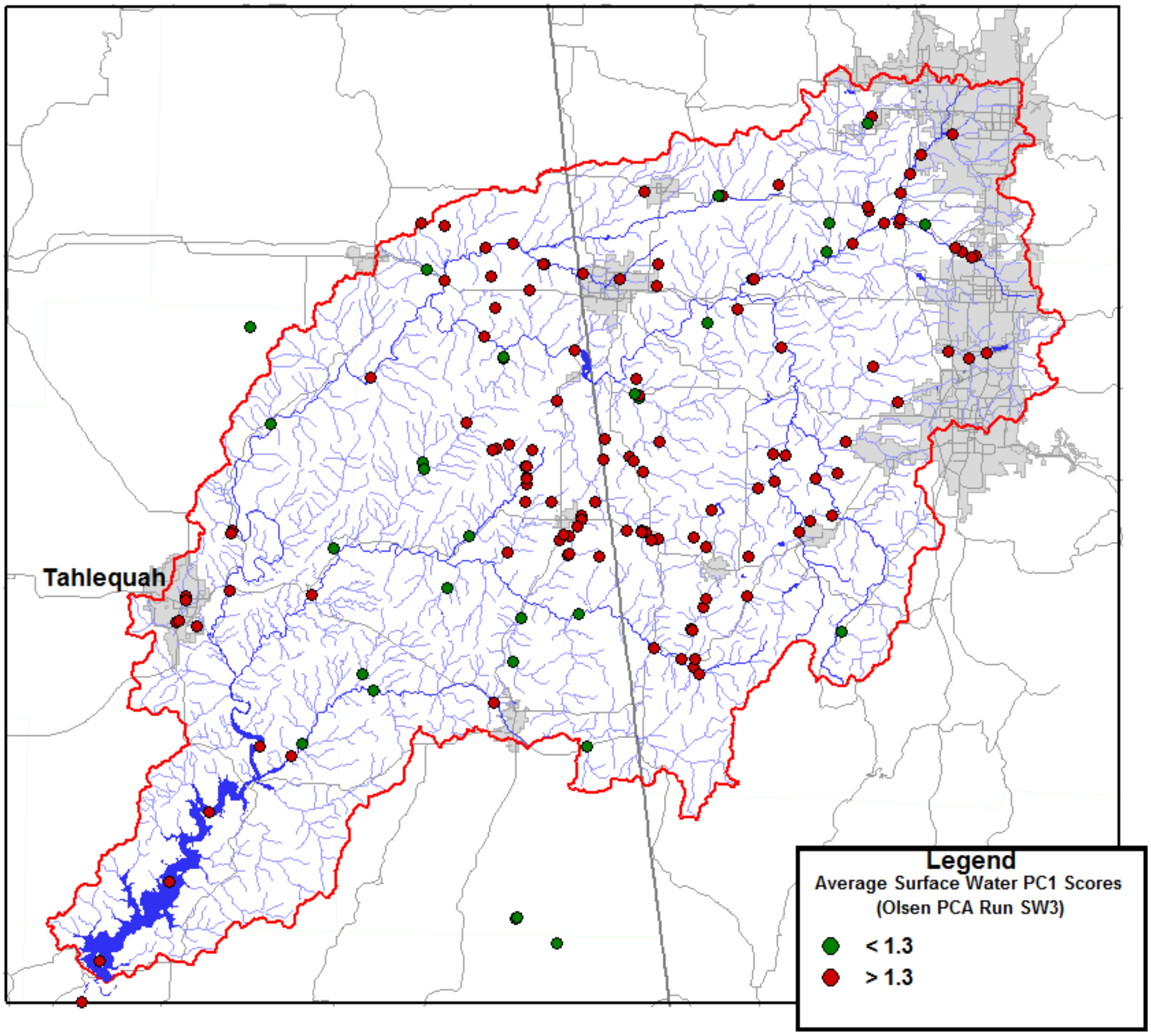



**Figure 3-1.** Reproduction of Olsen Figure 6.11-23.
Map generated using PC1 scores reported in Olsen's Appendix F, and the 1.3 PC1 threshold criteria indicated by Olsen. Note that in contrast to Olsen's Figure 6.11-23, all Tahlequah samples on this figure plot as green dots rather than red-dots.

In addition, when we highlight these six Tahlequah samples on Olsen's SW3 scores plot (Figure 3-2) we see that all six not only exceed his 1.3 poultry-impact threshold, they all plot within Olsen's "*Poultry Waste Dominant Impact*" area. Olsen appears to have changed the color of the Tahlequah samples on his Figure 6.11-23 because the PCA results did not agree with his theory. But nowhere on his red-dot green-dot map, and nowhere in the text of his report does he disclose this to the reader. Four months after submitting his report, in deposition testimony, Olsen did acknowledge it. After confirming that the Tahlequah samples were shown as green dots on his figure, Olsen was asked to turn to his table that lists Principal Component 1 scores, whereupon Olsen interjected the following:

> ***Q*** *Okay. Dr. Olsen, could you go to the table that reports your Principal Component 1 scores for SW3?*
> ***A*** *Yeah. Let me cut you short here now that we brought those up. Those were above 1.3, but based on the spatial analysis, I decided that those were not impacted by poultry, and I colored them green to this analysis of the percent.*[71]

[71] Olsen Deposition 9/11/08. p. 405.

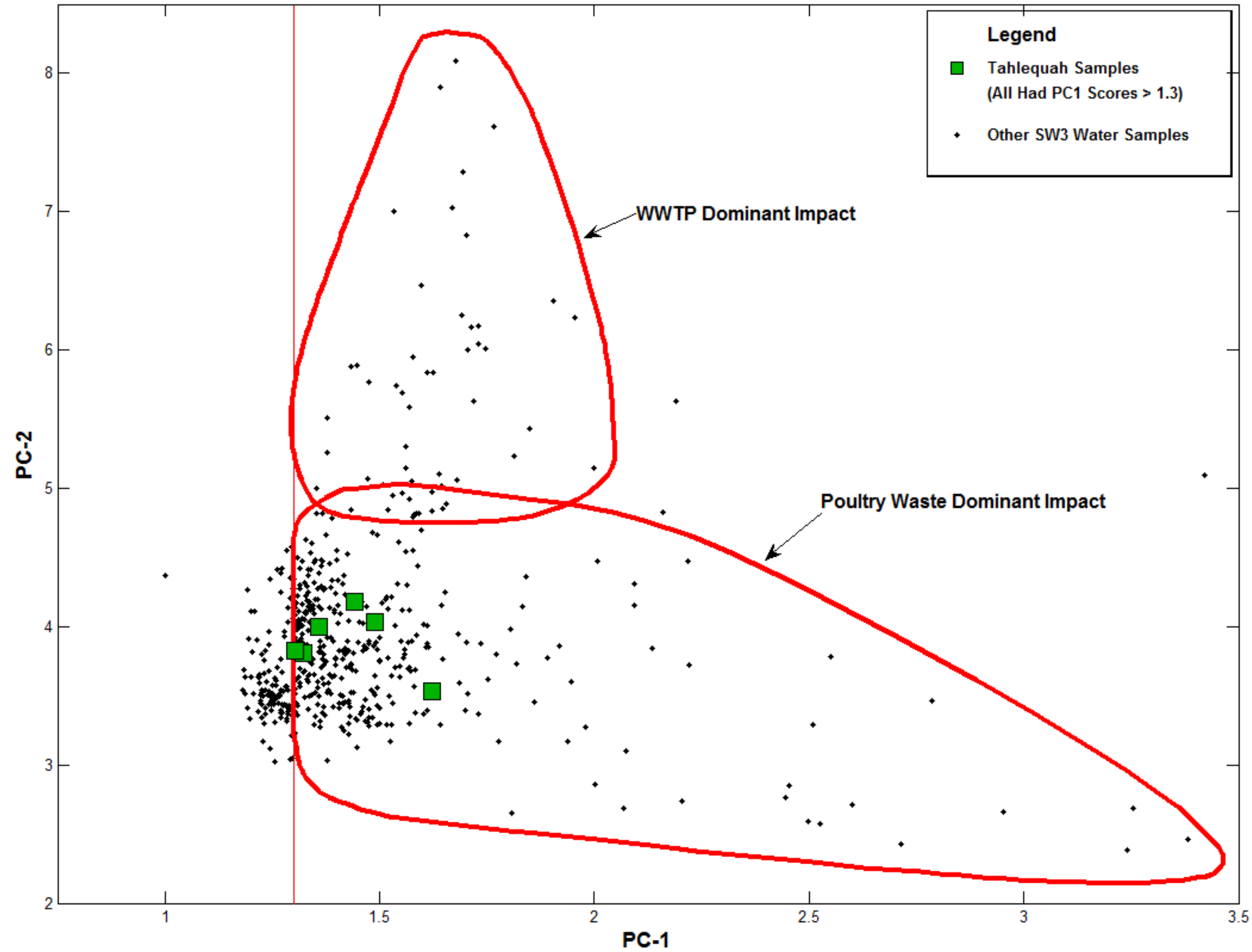



**Figure 3-2.** Olsen's SW3 scores plot (expanded view) with the six Tahlequah samples highlighted.

Olsen then acknowledged that (1) his decision to change the Tahlequah was subjective; (2) it was made as a result of his spatial analysis, (3) he never disclosed it to the reader, (4) his treatment of the Tahlequah data is misleading, and (5) he should have disclosed all of this in his report.[72] But consider this also in context of Olsen's original rationale for conducting a spatial analysis. The spatial analysis was offered by Olsen as a confirmatory line of evidence in support of his opinion that samples with PC1 scores greater than 1.3 exhibit a *unique poultry waste signature*.[73] In reporting the results of the spatial analysis, he discussed only five sample locations, all of which were consistent with Olsen's interpretation.[74] This was offered by Olsen as evidence that his 1.3 PC1 threshold was supported by an independent data set: poultry house density.[75] Olsen now admits that he knew that PC1 scores in Tahlequah did not support that theory, and offers this same spatial analysis as the justification to veto his own criterion.

Clearly, Olsen's spatial analysis serves more than one purpose. When it supports his opinion, it is offered as an independent line of evidence, used to validate his *unique poultry waste signature* criterion. But when it contradicts his opinion, it is used quite differently. The spatial analysis

[72] Olsen Deposition 9/11/08. p. 408-409.
[73] Olsen (2008a). p. 6-34 (Steps 12 and 13 bullets); p. 6-57 (4th paragraph); p. 6-59 (2nd paragraph). p. 6-60 (1st paragraph). Olsen Deposition testimony (9/10/08; p. 220).
[74] These 5 were consistent with Olsen's theory, if we grant him the latitude to round HFS30 data down from 1.30226 to 1.3 – see Section 2.3.1.
[75] Olsen (2008a). p. 6-59 to 6-60.

becomes the justification to recolor red-dots as green-dots, and make them appear to be consistent with his theory. Olsen's spatial analysis is instrument of convenience.

## 3.2 Waste Water Treatment Plant Samples

Waste water treatment plant samples (WWTP) are another example of where Olsen's PCA interpretation is not supported by his spatial analysis. Olsen collected four samples with the intent of characterizing the chemical/bacterial composition of WWTP sources. Three of these were actual effluent samples collected at the Siloam Springs, Springdale and Rogers plants (Figure 3-3). The fourth was given the sample name 'Lincoln WWTP', and was collected just downstream of the Lincoln WWTP (Figure 3-3).

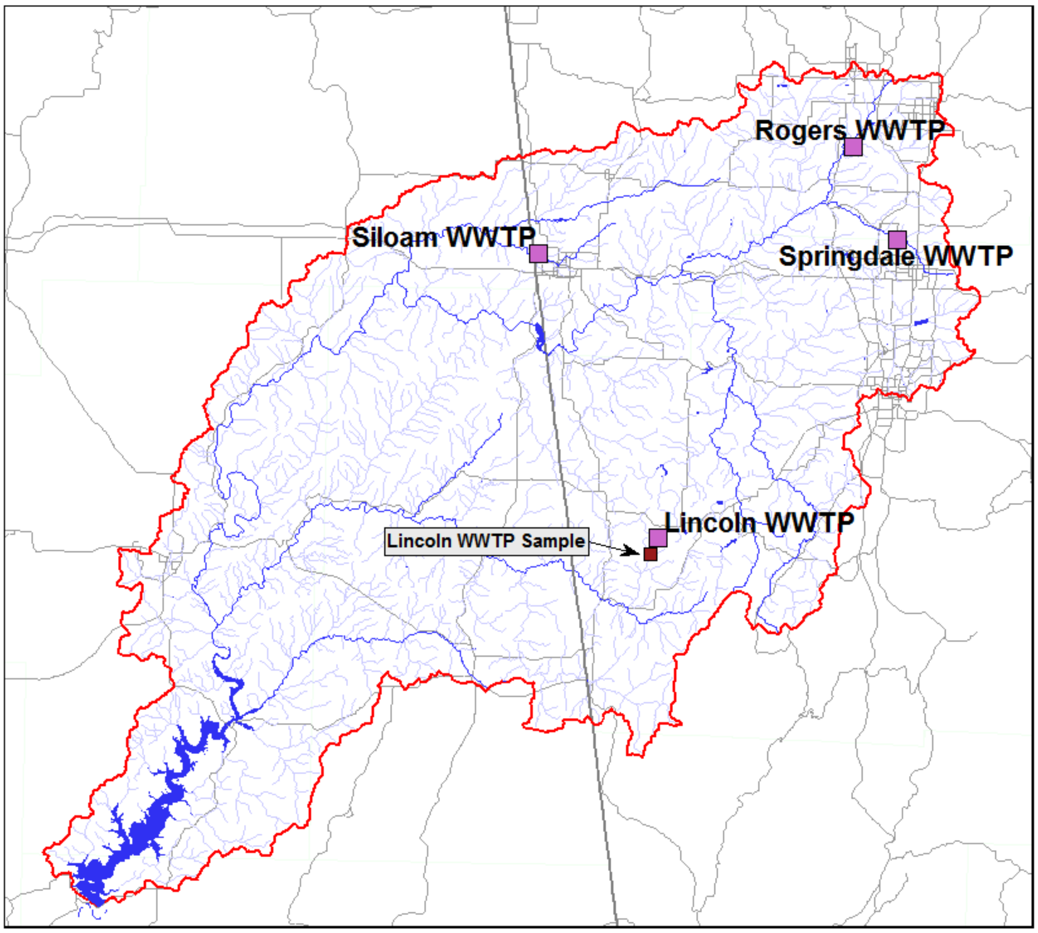



**Figure 3-3.** Map showing locations of Olsen's WWTP samples.
Rogers, Springdale and Siloam Springs WWTP samples were actual effluent samples. Lincoln was a surface water sample collected <2,000 feet downstream of the Lincoln WWTP (See Figure 3-5).

All four of these samples were included in Olsen's SW3 PCA run. Figure 3-4 shows the SW3 scores plot, with these samples highlighted and labeled. The three effluent samples plot within Olsen's WWTP Dominant Impact area, but they also exhibit PC1 scores above his 1.3 PC1 threshold for poultry impact. The fourth sample ("Lincoln") collected downstream of the Lincoln WWTP actually plots within Olsen's "*poultry waste dominant impact*" area. The fact that all four samples yield PC1 scores greater than 1.3 is a major contradiction to Olsen's theory of a PC1 threshold of 1.3 for determining the presence of a unique poultry signature.

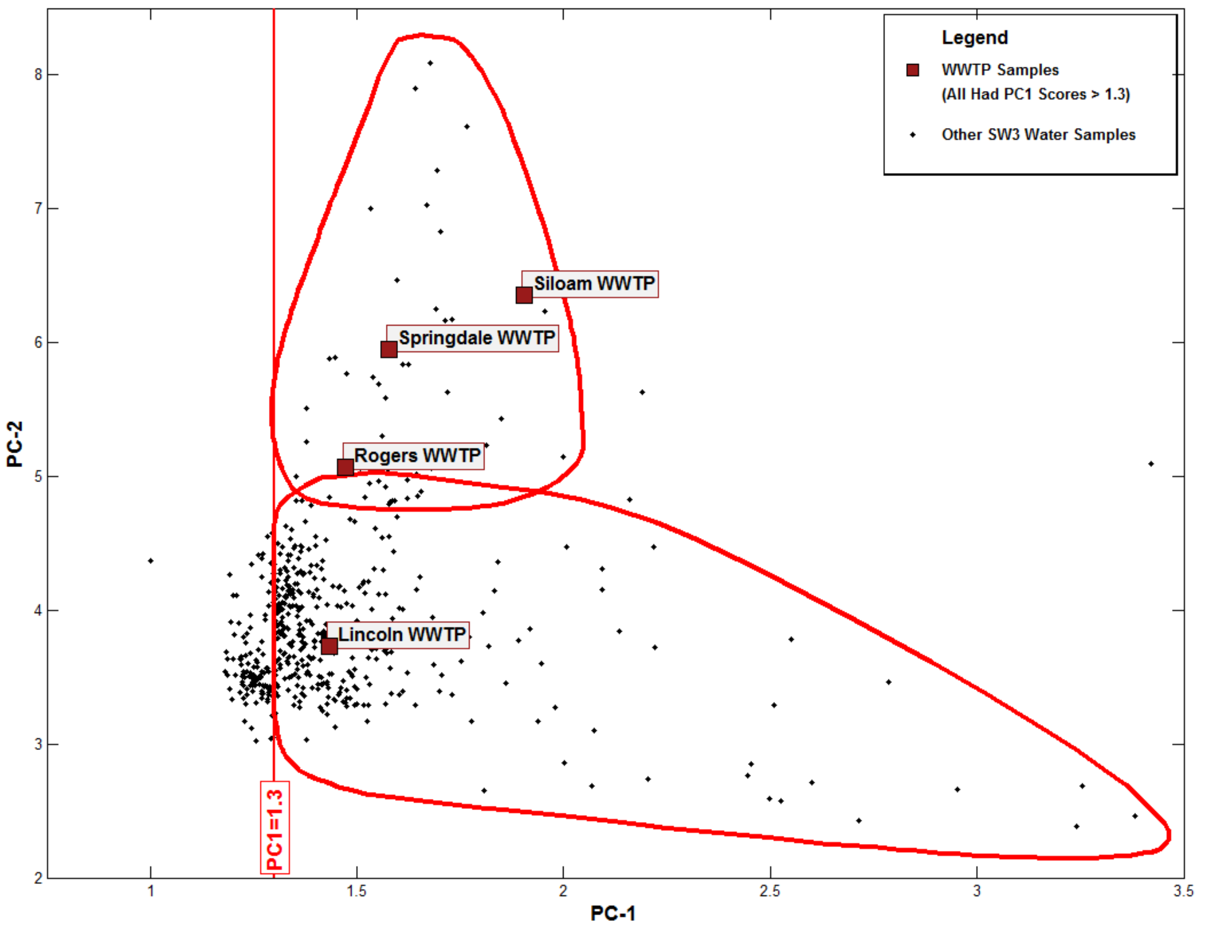



**Figure 3-4.** Olsen's SW3 scores plot (expanded view) with the four WWTP samples highlighted. All exhibit PC1 scores above Olsen's poultry impact threshold.

Like Tahlequah, Olsen's PCA classification of these samples as "*poultry impacted*" is not supported by his spatial analysis. But unlike Tahlequah, Olsen did not veto his 1.3 criterion. He showed them as red-dots on his Figure 6.11-23, and counted them among his poultry-impacted samples in his percentage calculations. In deposition, Olsen acknowledged that the three WWTP effluent samples all had PC1 scores greater than 1.3 and conceded that (1) they should not have been classified as poultry-impacted samples; and (2) they needed to be removed from his poultry-impact percentage calculations.[76] Two weeks later (9/24/08) Olsen submitted an erratum where the WWTP effluent samples (Siloam, Springdale and Rogers – but not Lincoln) were removed from his percentage calculations. The revised text neither acknowledged nor explained the inconsistency of having all WWTP effluent samples exhibit PC1 scores greater than 1.3. Even though the Siloam, Springdale and Rogers WWTP samples span a wide range of Olsen's "WWTP Dominant Impact" area (Figure 3-4) Olsen maintains that all other samples within the WWTP red-oval are poultry impacted. He makes no change in the classification of stream water samples as a result of his original error in classification of the three WWTP effluent samples.[77]

Olsen acknowledged that the intent of the Lincoln sampling was to get as close to the POTW outfall as possible.[78] But in contrast to Siloam, Rogers and Springdale, he did not change his

[76] Olsen Deposition. 9/10/08. pp. 274-275. 9/11/08. pp. 335-336.
[77] Olsen Deposition. 9/11/08. pp. 335-336.
[78] Olsen Deposition. 9/11/08. pp. 557-558.

classification of Lincoln WWTP as '*poultry impacted.*'[79] Neither did he address the degree to which his spatial analysis supported a conclusion of poultry-impact in this area, downstream of Lincoln.[80] Figure 3-5 shows a map of the location of the Lincoln WWTP sample, in relation to Olsen's poultry house density data and the Lincoln POTW. It is located in an area of low poultry house density, within a 1.5 km of Lincoln and its POTW outfall. A spatial analysis does not support the classification of this sample within the '*predominantly poultry-waste impact'* area of the scores plot.

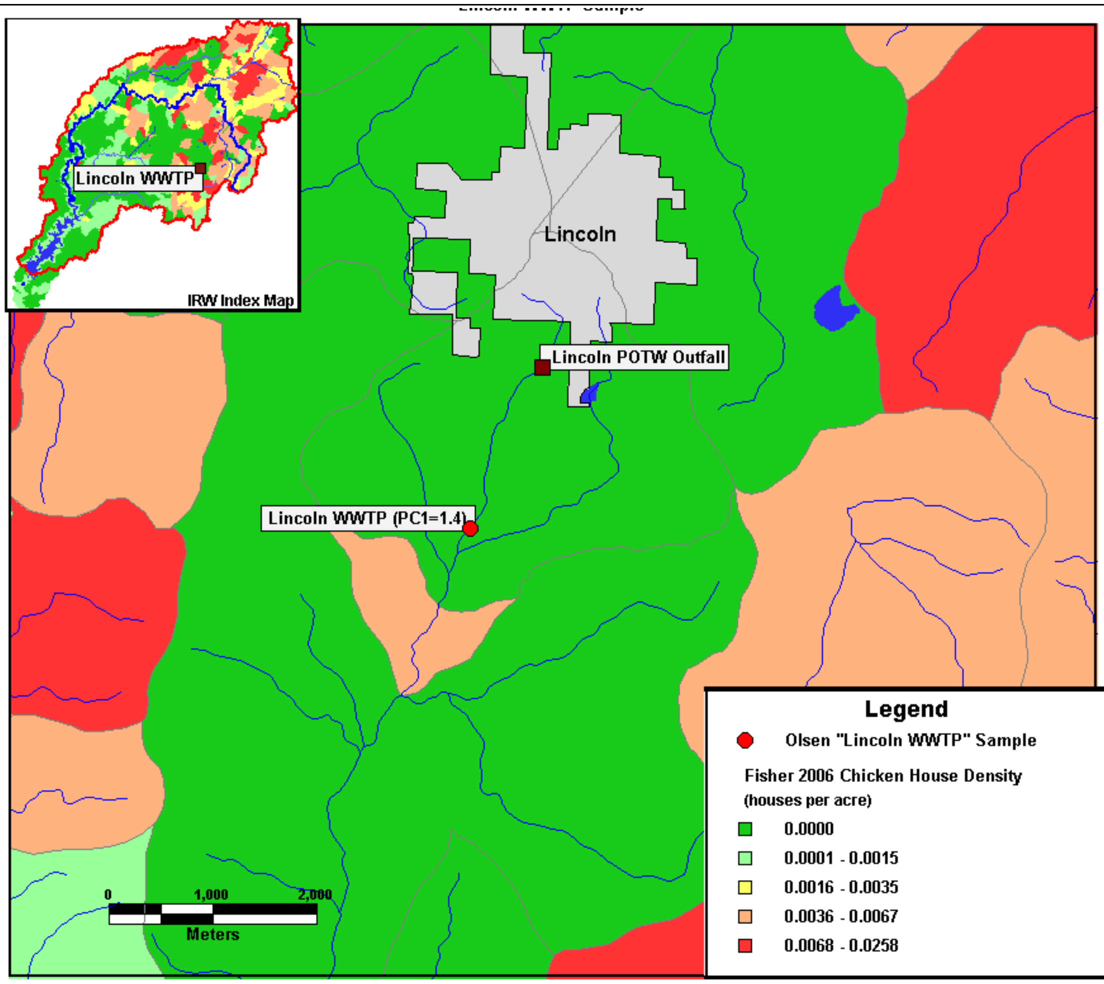



**Figure 3-5.** Location of Lincoln WWTP sample with respect to poultry house density & Lincoln POTW. Poultry House Density data from Olsen production. Lincoln POTW location from Jarman (personal communication).

[79] Olsen Deposition. 9/10/08. pp.276-277.
[80] Olsen Deposition. 9/11/08. pp. 558-559.

## 3.3 Cattle Impacted Samples

In Section 2.2.3, I briefly summarized the argument Olsen used to try to dismiss cattle manure as a source of contamination in the IRW. This section provides a more detailed critical review of that argument, as well chronological summary of how Olsen's cattle-impact argument has changed over time.

### *3.3.1 History of an Ever-Changing Cattle Impact Argument*

#### *3.3.1.1 February 2008: The Cattle Argument at the Time of the PI Hearing*

As part of the Preliminary Injunction (PI) process, Olsen testified that his PCA differentiated three sources of contamination in the IRW: (1) poultry, (2) waste water treatment plants; and (3) cattle waste. Olsen testified to his ability distinguish between poultry, wastewater and cattle, and concluded that cattle waste inputs were not an important contributor.[81]

In that testimony, Olsen made it clear that he believed his PCA gave him the ability to distinguish between these three sources, but, he did not articulate a specific PCA criterion for what he considered "cattle impacted" (i.e. was it PC1 > 1.3, or PC2 > 4.7, or PC3>2). Two weeks after this deposition, in a February 14, 2008 email to counsel and members of his technical team[82] Olsen included the two hand-annotated PCA scores plots shown below (Figure 3-6).

The general shape of the data cloud is very similar to what we see in the SW3 and SW22 score plots presented by Olsen in his May 14 final report (see Figures 2-1 and 2-9 of this report). Most of the data plot within an L-shaped data cloud. His annotation of these graphs indicate that he interpreted samples located along the bottom of the "L" as "*poultry dominance*" and samples plotting along the vertical part of the "L" as *WWTP dominance*." This is essentially the same interpretation as is reflected in his final report. But the cattle criterion is different. His hand-annotated PC scores plots show cattle-impacted samples all plotting away from (to the upper right of) the main part of the L. This hand-annotated scores plot sheds light on Olsen's subsequent PI hearing testimony:

> *"My conclusion is that the cattle signature is not significant. <u>I went to specific samples that I knew had cattle waste in it and I could see a distinct difference, particularly with the poultry waste</u>. So <u>**I knew what I was looking for** and it just wasn't a dominant signature</u> across the basin. I found it in, like, significantly in one spring sample and I found it not significant in three other spring samples. I found it significant in four edge of field samples and not so significant in five others. So it's just not a dominant signature across the basin. <u>If it would have been, I would have found it</u>."*[83]

This February 2008 testimony provides no hint of the cattle criteria that is ultimately reflected in his May 2008 report. Olsen says nothing about cattle-impacted samples "*exhibiting very different PC scores*" or the observation that some cattle impacted samples plot within both his WWTP and poultry dominant impact areas. Specifically, Olsen does not identify cattle impacted samples plotting in his WWTP oval or his poultry-impact oval. Instead he testified the he knew exactly what he was looking for, he saw distinct differences between cattle and poultry, and if cattle had been more dominant, he would have seen it. But bear in mind: this testimony predates both the collection of the cow-pasture edge of field samples (March 31, 2008), and Olsen's May 14, 2008 expert report.

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[81] See Olsen PI Deposition. 2/2/08 pp. 93-97; 100-102. Preliminary Injunction Hearing. 2/ 21/08. pp. 844-845.
[82] OlsenCORR0015829-15833
[83] Olsen Preliminary Injunction Hearing Testimony. February 21, 2008. pp. 844-845. Emphasis added.

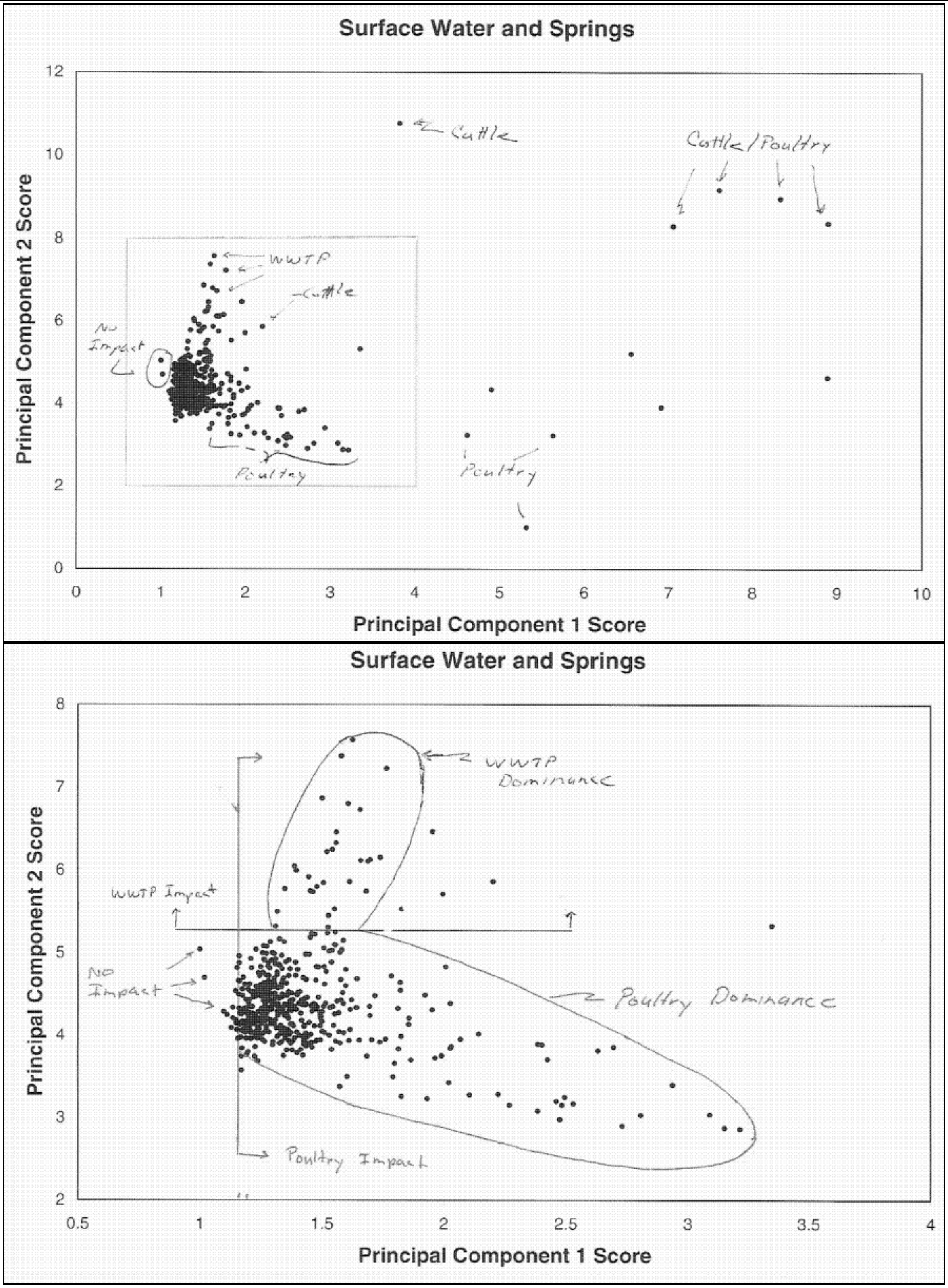


**Figure 3-6.** Olsen's hand-annotated scores plots: February 14, 2008 (surface-water and springs)
The lower scores plot is a zoom-in on the box-framed area shown in the upper plot. (Source: OlsenCORR0015833).

#### *3.3.1.2 May 2008: The Cattle Argument in Olsen's Report.*

The cattle manure argument that appears in Olsen's report (pages 6-61 and 6-62 of his report) is summarized and reviewed in Section 2.3.3 of this report, and differs from that presented as part of his February PI testimony. His PI testimony indicated that he believed that there was distinct separation between cattle and poultry samples on a scores plot. In contrast, his May 2008 report, points to "*four samples documented with cattle contamination*"[84] that plot across a wide ranging area of the scores plot, including areas of WWTP and poultry dominance. Most importantly, two of these four samples (cow-pasture edge of field samples collected after the PI hearing) actually plot within Olsen's '*poultry-waste impact dominant*' area (see Figure 2-9). As a result, we get a new argument in May 2008, as seen in the following three quotes:

- "*if cattle waste were a major impact on contamination in the IRW, a dominant signature should be observed in the PCA.*"[85]
- *"These four samples have very different PC scores and no consistent relation or group is observed in the PCA."* [86]
- "*If cattle contamination contributed significant impact to contamination in the IRW, a clear signature and associated group should be observed in the PCA and the four samples would be in a group."* [87]

Olsen's May 2008 opinion has not changed, but the argument that gets him there has. Olsen no longer expects cattle-impacted samples to be distinctly separated from poultry and/or WWTP-impacted samples on a scores plot. Instead he points to two samples that plot within the poultry-impact area, another that plots within the WWTP impacted area, and a fourth that plots separately from both areas, and cites this range of variability as evidence that there is no dominant signature for cattle.

As pointed out in Section 2.3, this argument completely ignores a major contradiction to Olsen's PCA interpretation. All "*four samples documented with cattle contamination*"[88] exhibit PC1 scores greater than 1.3. Olsen's report never acknowledges this. Nor did he acknowledge that the two cow pasture edge of field samples collected after the PI hearing (EOF-CP-1A and EOF-CP-1B) actually plot within his poultry- dominant area.

Olsen also concealed another interesting bit of information that contradicts his argument. Olsen's Figure 6.11-25 (SW22 scores plot reproduced here as Figure 2-9) shows cattle-impacted sample SPR-26 plotting as a single sample. With respect to that sample, Olsen wrote that "*one of the spring samples (SPR-26) plots within the WWTP impact area.*"[89] There are actually two SPR-26 samples in SW22. Only one of these plots within Olsen's *WWTP impact area*. The other plots within Olsen's *poultry-waste dominant impact* group (PC1>1.3, PC2<4.7: see Figure 3-7 below). Olsen concealed this by taking the average of the two SPR-26 scores, and plotted the average on his Figure 6.11-25. Had Olsen not taken the average, his cattle impact argument would appear even weaker, because three of five "*samples documented with cattle contamination"*[90] would have plotted within an area of the scores plot that he interpreted as predominantly impacted by poultry. This graphical slight-of-hand obscures the fact that his "*unique poultry waste signature*" is not that unique.

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[84] Olsen (2008a). p. 6-62 (line 5).
[85] Olsen (2008a). p. 6-61 (last line) through p. 6-62 (2nd line). (emphasis added).
[86] Olsen (2008a). p. 6-62 (lines 13-14).
[87] Olsen (2008a). p. 6-62 (lines 14-17).
[88] Olsen (2008a). p. 6-62. Lines 4-6.
[89] Olsen (2008a). p. 6-62. 1st paragraph.
[90] Olsen (2008a). p. 6-62. Lines 4-6.

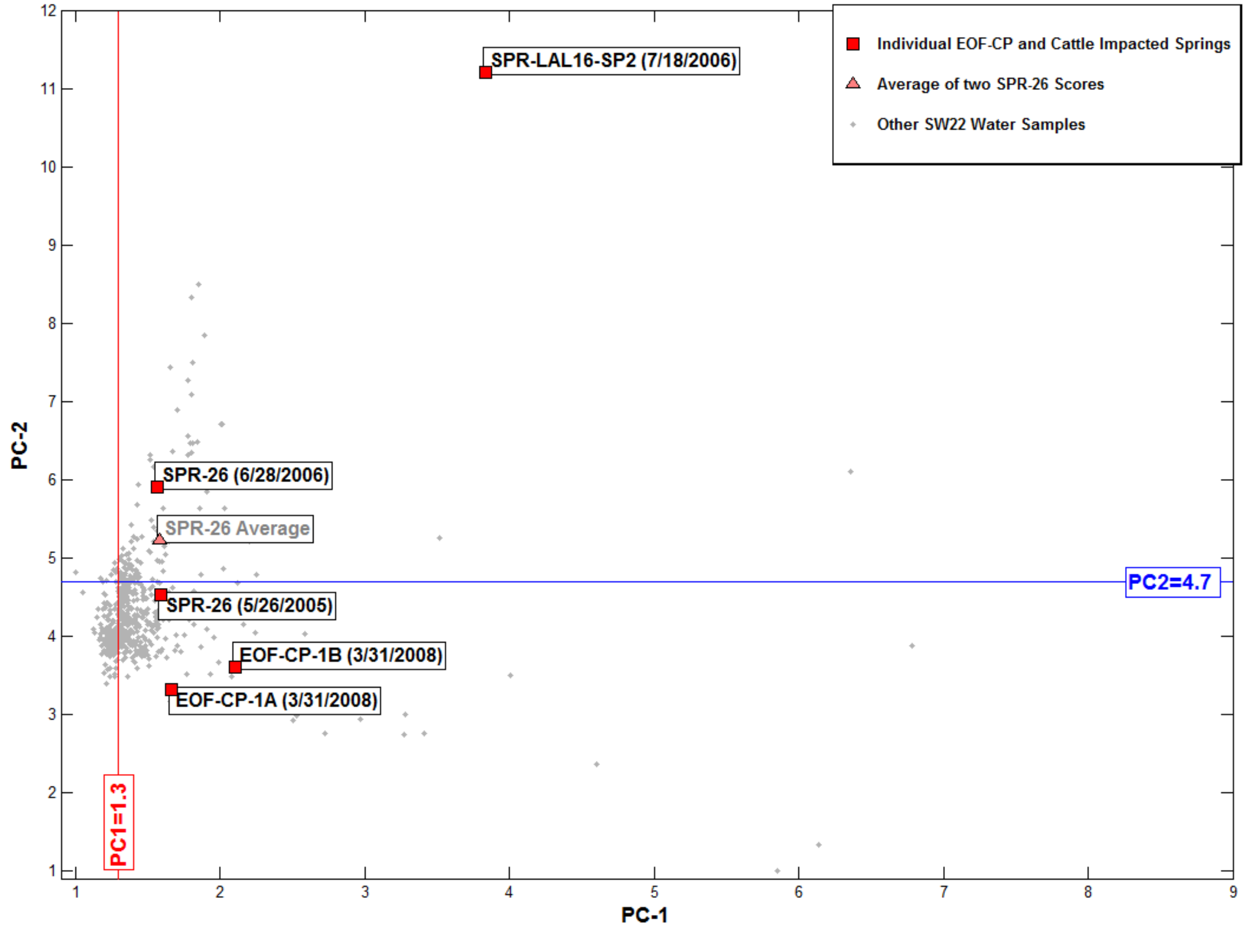


**Figure 3-7.** SW22 scores plot with cattle impacted edge-of-field (CP) and cattle impacted spring (SPR) samples highlighted.

Moving beyond this bit of deception, let's explore the logic Olsen's May 2008 cattle-impact argument in more detail. The argument is based on Olsen's premise that if cattle had a major impact, we would expect to see known cattle-impacted samples plotting as a single, clear and distinct group. According to Olsen, the fact that they do not (i.e. they plot across a wide ranging area of the scores plot) constitutes evidence that cattle-waste is not a major contributor. What if another group of samples, related to another suspected source, exhibited a similar wide range of variability? If we follow Olsen's logic, we should similarly conclude that it is not a "*dominant signature.*" With the exception of the two cow-pasture edge-of-field samples, Olsen claims that all other edge-of-field (EOF) samples reflect primarily poultry litter impacts.[91] SW3 included 63 EOF samples. These 63 samples (and the 2 EOF-CP samples) are highlighted on the SW3 scores plot in Figure 3-8.

[91] Olsen Deposition. pp. 51-52.

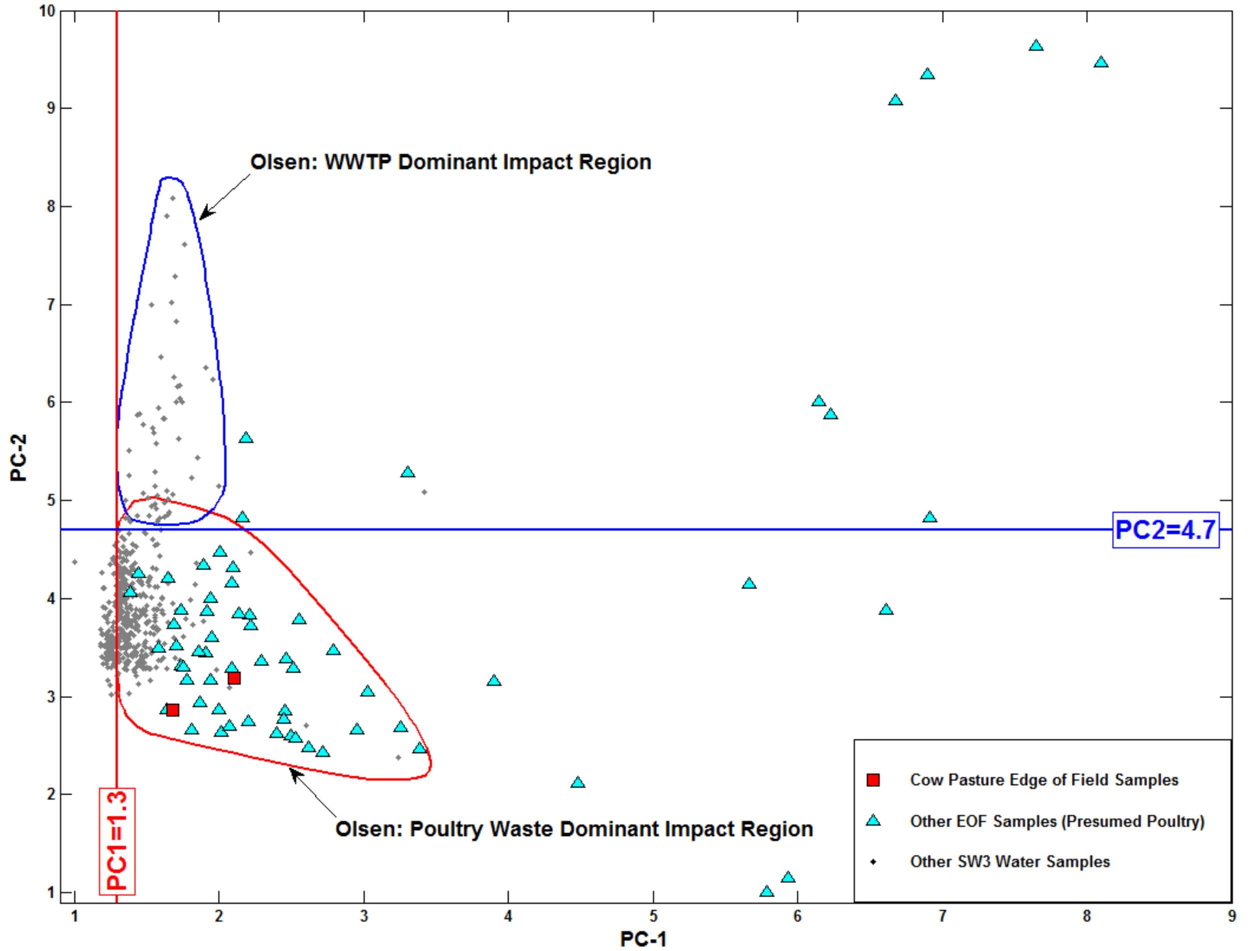


**Figure 3-8.** SW3 scores plot with EOF-CP and other EOF (presumed poultry) samples highlighted.

Note that the edge-of-field samples that Olsen presumes are poultry-impacted do not exhibit a "*clear signature and associated group.*" They have very different PC scores and no consistent relation or group is observed. This is exactly what Olsen described for the four cattle impacted samples in SW22[92] and was the rationale for dismissing cattle as a contributor to the IRW. The range of variability of the 63 presumed poultry-impacted EOF samples spans almost the entire range of the scores plot. Along the PC1 axis EOF scores range from very near Olsen's 1.3 poultry-impact threshold up to his maximum PC1 score of 8.1. Along the PC2 axis the EOF scores span the entire range from the minimum to maximum. Ten EOF samples actually exceed Olsen's "WWTP dominant impact" threshold of 4.7. Olsen's May 2008 cattle impact argument is poorly reasoned. In developing it, he relies on a conveniently ambiguous definition of "dominant signature." His logic is flawed because when you turn the same method to suspected poultry-impacted edge of field samples (the source that he claims is the dominant contributor to IRW surface waters) we see a similar range of variability. If you buy the premise of Olsen's May 14 cattle argument (i.e. what he would expect to see if cattle manure impacts were significant) the same logic should have led him to dismiss poultry as a significant source.

[92] Olsen (2008a). p. 6-62 (lines 13-17).

#### *3.3.1.3 September 2008: The Cattle Argument Provided in Deposition Testimony.*

Between Olsen's May 2008 report and his September 2008 deposition testimony, Olsen's cattle argument changed yet again. In May, the two EOF-CP samples (EOF-CP-1A and EOF-CP-1B collected on the property of Ed Fite) were characterized by Olsen as "*samples documented with cattle contamination*."[93] In his September testimony, Olsen acknowledged that they exhibited PC1 scores greater than 1.3[94] and backed off of his position that they represent cattle-impact. He opined instead that they represent poultry-impact.[95] But he also confirmed that that (1) these samples were collected with the intent of capturing runoff representative of a pasture where cattle had been grazed,[96] (2) he had no evidence that poultry litter was ever applied on the property where the EOF-CP samples were collected,[97] and (3) his opinion that EOF-CP samples are poultry-impacted is speculation.[98] In deposition, Olsen offered caveats regarding the representativeness of the EOF-CP samples,[99] advised caution in how those data should be considered,[100] but conceded that his May 14 report included no such cautions.[101]

There is no evidence to support Olsen's speculation that the cattle edge-of-field samples are impacted by poultry.[102] The CP-EOF samples were collected on March 31, 2008 on the property of Ed Fite. Field notes taken at the time of their collection state: "*This field has never been applied with poultry waste*."[103] In addition, when you look at these data in context of Olsen's spatial analysis (in particular his poultry-house density data) it does not support Olsen's speculation (Figure 3-9). These samples were collected in an area of low poultry house density.

Olsen's most recent cattle argument is not only based on speculation, it is contradicted by the very data that he relied on elsewhere to justify his interpretations.

[93] Olsen (2008a). p. 6-62. Lines 4-6.
[94] Olsen Deposition 9/11/08. pp. 369.
[95] Olsen Deposition. 9/10/08 p. 282. (Lines 15-24). 9/11/08. p. 388 (Lines 1-17).
[96] Olsen Deposition 9/10/08. pp. 52-53.
[97] Olsen Deposition. 9/10/08. p. 54.
[98] Olsen Deposition. 9/11/08. p. 388 (Lines 18-19).
[99] Olsen Deposition 9/10/08. pp. 52-53.
[100] Olsen Deposition. 9/10/08. p. 55 (Lines 15-25).
[101] Olsen Deposition. 9/10/08. p. 56 (Lines 5-8).
[102] Olsen Deposition. 9/11/08. p. 388 (Lines 18-19).
[103] See Field CDM/Lithochimea field notes from March 31, 2008 (STOK005374).

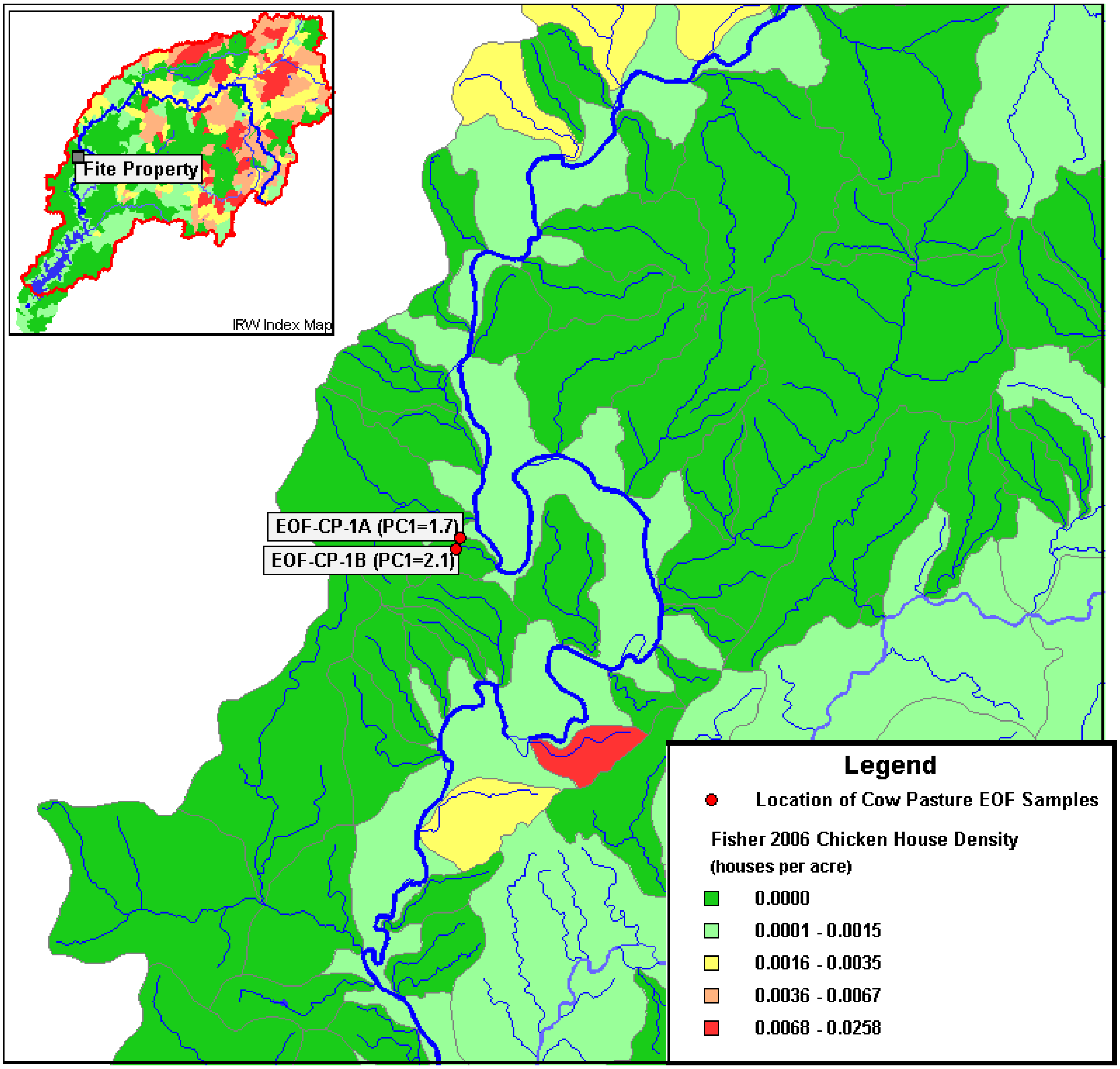


**Figure 3-9.** Locations of EOF-CP samples plotted on Olsen's poultry house density basemap. Note that the EOF-CP samples are located in area of zero poultry-house density, yet the PC1 scores of both samples both yielded PC1 scores greater than Olsen's 1.3 poultry impact threshold.

### 3.3.2 Olsen was Aware of This "Problem" and Concealed It

In his May 14 report, Olsen never acknowledged that his "*samples documented with cattle contamination*"[104] all had PC1 scores > 1.3, or that there was overlap between EOF-CP and other EOF samples. However, it is clear from emails produced by Olsen that his failure to disclose it was not because he missed these points, or failed to appreciate their significance. Emails between Olsen and an associate that ran the statistical software for him, indicate that within the final two weeks before Olsen's report was due, they were actively trying to find a PCA run that would yield a scores plot with distinct separation between poultry EOF and cow pasture EOF samples. The emails below were exchanged on May 2, 2008, after nineteen PCA runs (out of 22 total in his report) had been completed.

---

**Fri 5/2/2008 8:30 AM**
**From:** Richard Chappell
**To:** Roger Olsen
**Subject:** PCA run SW 19 posted

**Water_0502_SW_19**
Same as SW 18 but removed the two FAC samples - so it's just EOF and Manure Leachate.

---

**Fri 5/2/2008 9:54 AM**
**From:** Olsen, Roger
**To:** Chappell, Richard
**Subject:** Looked at runs - one more

I looks at the runs - good confirming things.
I think we should run an EOF only run - see if the EOF - CP will break out. Thanks.

---

**Fri 5/2/2008 11:06 AM**
**From:** Richard Chappell
**To:** Roger Olsen
**Subject:** RE: Looked at runs - one more

Posted: **Water_0502_SW_20**
EOF only run, 26 variables, >=20 cutoff, total metals. On **R_PC_Plot** the CD [sic] samples are indicated on the variomax plots (and a few of the no rotation plots) as yellow symbols - they don't seem to break out, although they are kind of toward the edge on alot of the plots. I'm looking at the chemistry some more to see if there are any particular variables that differ from the rest of the EOF - if so, we may be able to break them out using a reduced set of variables.

Have you received any further information about those samples?

---

Recall that Olen's February 2008 cattle-impact criterion was based on separation of presumed cattle impacted samples and poultry-impacted samples on a PCA scores plot (see Section 3.3.1.1). But the March 2008 cow-pasture edge-of-field samples (CP) did not support that criterion. Those two samples plotted squarely within Olsen's "*poultry-waste dominant impact*" area (see SW3 scores plot: Figure 2-12). On May 2, after 19 PCA runs, Olsen was apparently still trying to find a way to "*see if the EOF - CP will break out.*" That is, he was trying to find a PCA run that supported his February PI testimony. SW20 was run with that specific purpose.

The SW20 varimax plots referred to in the 3rd email were not included in Olsen's production, but the results spreadsheets for PCA run SW20 were. It is a simple matter to make a varimax scores plot using those results (Figure 3-10 below). On this plot, we see exactly what was reported to Olsen in the email above: there is no separation between EOF-CP and other EOF samples.

[104] Olsen (2008a). p. 6-62. Lines 4-6.

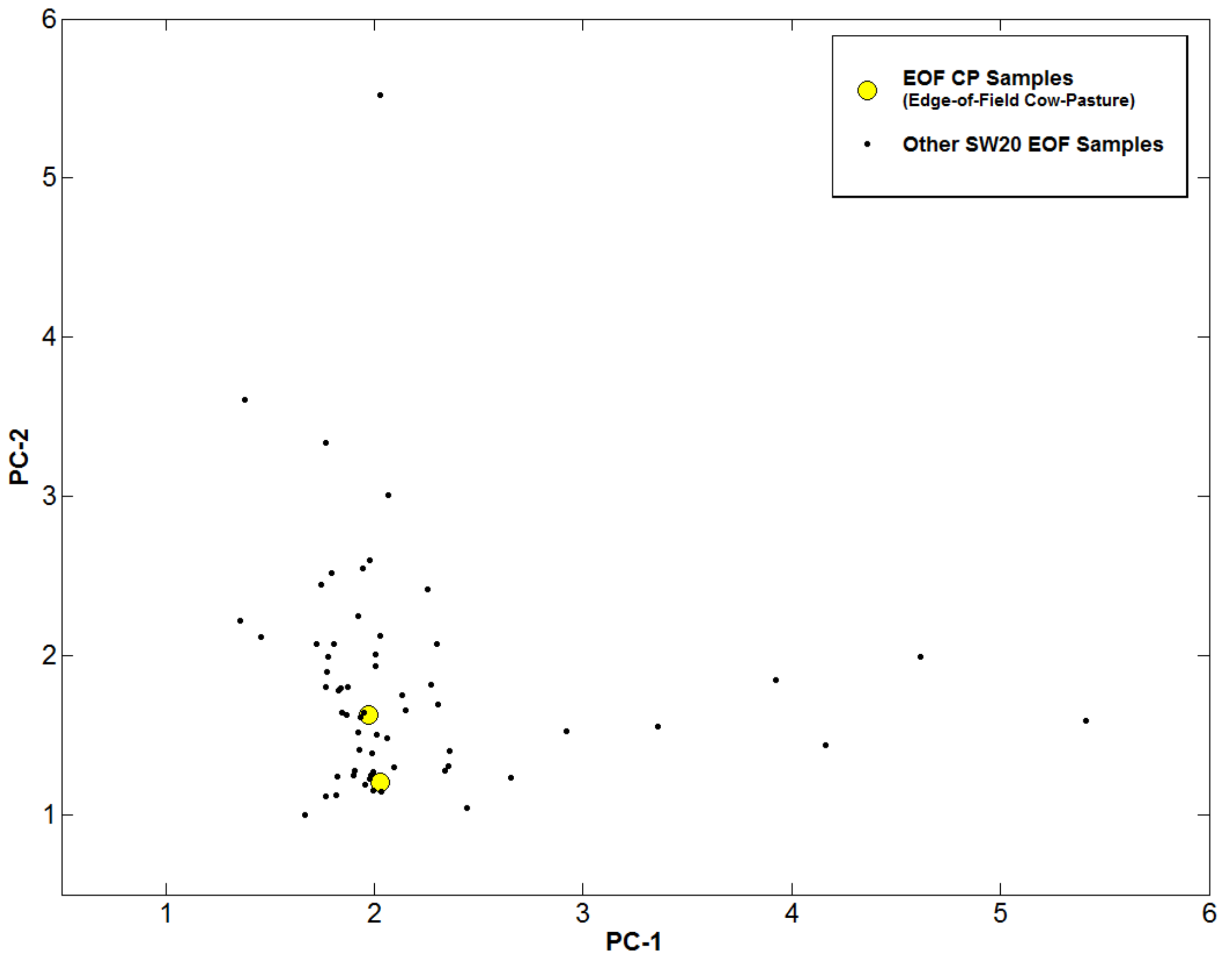


**Figure 3-10.** SW20 Scores Plot (Varimax Rotation).
Data taken from Spreadsheet ('Results_Water_0502_SW_20.xls') produced as part of Olsen considered materials. Note lack of separation between EOF CP and other edge-of-field samples.

In the same email where Olsen's associate (Chappell) reported the failure to get separation, he reported that "*I'm looking at the chemistry some more to see if there are any particular variables that differ from the rest of the EOF - if so, we may be able to break them out using a reduced set of variables.*" Two and a half hours later, the results of that analysis were back, in the form of PCA Run SW21.

**Fri 5/2/2008 1:37 PM**
**From:** Richard Chappell
**To:** Roger Olsen
**Subject:** RE: Looked at runs - one more
**Attachments:** Comparison_EOF_CP_Chemistry_26.xls; R_PC_Plot_Water_0502_SW_21.zip

I compared the 26 variables (see attached) then picked the 14 variables that were most different between the two CP samples and the EOF and ran a PCA. It put them more on the edge, generally, but still no distinct separation (see attached).

In this attempt to get "*distinct separation*" Chappell first conducted a comparison of the 26 variables in Olsen's main PCA water run (SW3). Based on that analysis, he identified 14 that he thought gave him the best chance of distinguishing between EOF-CP and other EOF samples. He then ran a PCA using <u>only</u> those variables. Despite cherry-picking the variables with the specific objective of getting separation between EOF-CP and other EOF samples, this attempt failed: "*still no distinct separation (see attached).*" This time, the score plots were included as an attachment to the email (Figure 3-11).

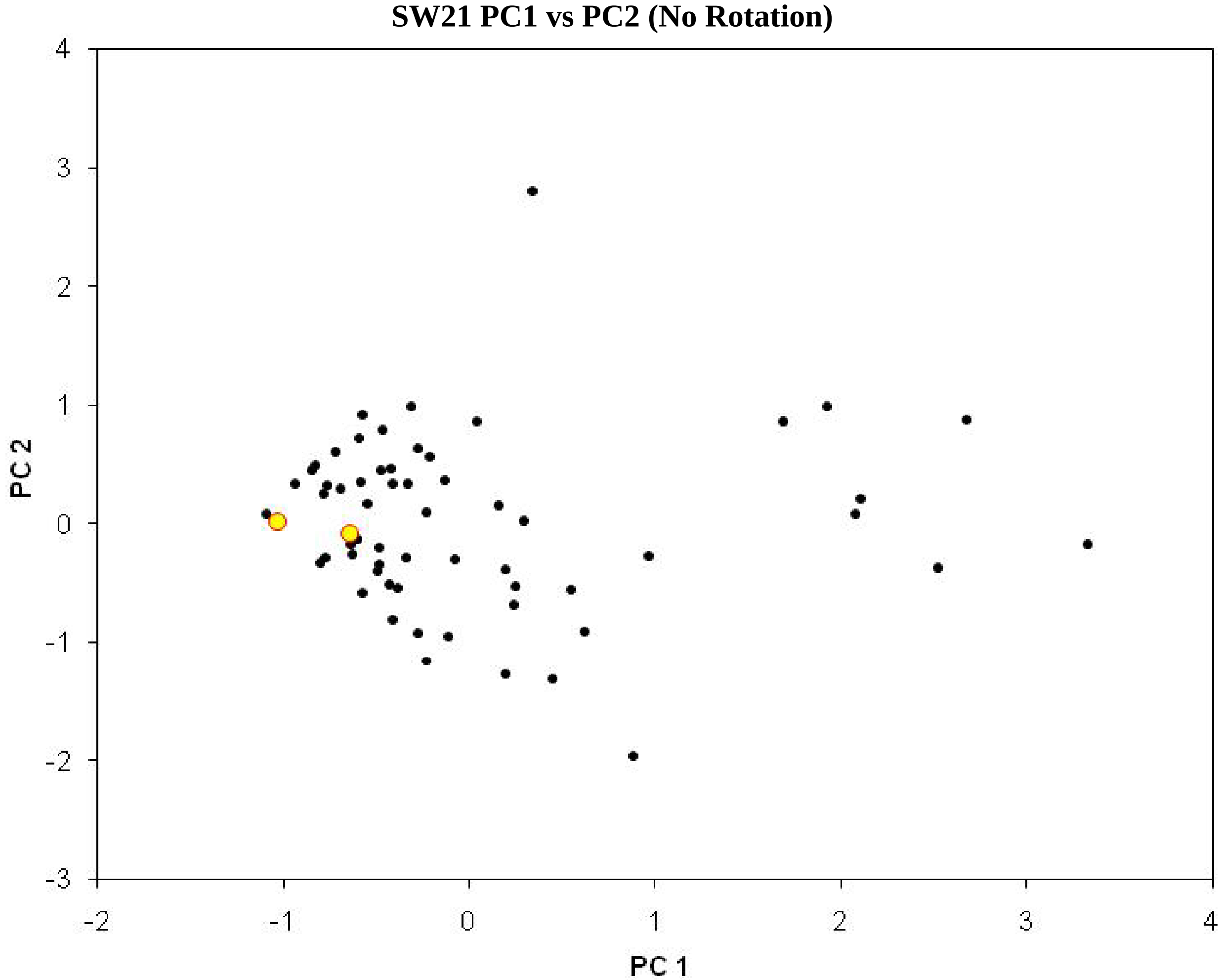


**Figure 3-11.** SW21 Scores Plot (No Rotation).
Plot included in spreadsheet ('R_PC_Plot_Water_0502_SW_21.xls') produced as part of Olsen considered materials, as attachment to 5/2/08 email from Chappell to Olsen. The yellow circles are the EOF-CP samples. The black dots are all other EOF samples in SW21. Note: no separation between EOF CP and other edge-of-field samples.

These emails make it clear that that as of Friday May 2, 2008, Olsen was holding out hope that the new cow-pasture edge-of-field data would support his concept of a distinct cattle signature, as per his PI testimony. He was looking for distinct separation between presumed cattle and poultry impacted samples. But PCA runs that included the new CP samples showed no such separation. He ran SW20 and SW21 with a specific objective: "*see if the EOF-CP will break out.*" They did not break out, and it was at this point that his cattle impact criterion changed. Two days after SW21 was run, (Sunday May 4 – ten days before the final report was due) Olsen ran one final PCA (SW22)[105] which became the basis of the cattle impact argument that appears his report (pages 6-61 and 6-62) and which is reviewed in Sections 2.3.3 and 3.3.1.3 of this

[105] See Olsen/Chappell email exchange. 5/4/08. 3:47 pm and 4:47 pm.

report. With this final PCA run, the criterion for distinguishing between cattle and poultry was no longer distinct separation, but rather the variability of scores.

Little of this is ever discussed in Olsen's report. But a detailed review of these PCA runs, the timing of emails that describe their purpose, and interpretation in context of the spatial analysis, indicate that he was well aware of evidence that contradicted his theory, and was less than forthcoming in his report.

- Olsen did not acknowledge in his report that all four cattle-impacted samples yielded PC1 scores above his *unique poultry waste signature* threshold.
- The score plots presented in Olsen's report from his primary PCA run (SW3) did not use a unique symbol for EOF-CP samples, so the reader cannot look at his figures and see that the two cow pasture edge-of-field samples plot within the boundaries of his "*poultry waste dominant impact*" area.
- In his report, Olsen never discussed the rationale for, or results from SW20 and SW21. But these PCA runs were implemented with the specific objective of getting separation between presumed cattle and poultry-impacted samples. They failed to meet that objective.
- In section 2.3.3 I noted that it was curious that PCA run SW22 was not included in Olsen's list of four "*major PCA runs*" [106] selected as such because they were "*the most important to the investigation or project objectives*."[107] This now makes a bit more sense. PCA run SW22 (and the associated cattle-impact argument in Olsen's report) was an afterthought. SW22 was run more than 2 months after Olsen's PI testimony, just 10 days before his report's due-date, and done so only when repeated PCA runs failed to support Olsen's previous argument, which had been based on distinct separation.
- Olsen's red-dot green-dot map ultimately shows the cattle edge-of-field samples as poultry impacted. But his spatial analysis does not support such an interpretation. The spatial analysis was supposedly an independent line of evidence in support of his interpretation.[108] In reporting the results of that effort, he presented just five examples, all of which were consistent with his interpretation.[109]
- The email exchanges quoted above indicates that these were not errors of omission. Olsen was fully aware of this contradictory evidence and its significance, and did not disclose it in his report.

In deposition, four months after his report, Olsen was confronted with these conflicting lines of evidence. Olsen now claims the EOF-CP samples (previously described "*samples documented with cattle contamination*"[110]) must considered with caution, and that they represent poultry impact, not cattle. Given three versions of Olsen's argument now, it is curious that his opinion never changes, only the argument necessary to get him there.

[106] Olsen (2008a). p. 6-51. Last paragraph.
[107] Olsen (2008a). p. 6-50. 3rd paragraph.
[108] Olsen (2008a). p. 6-34 (Steps 12 and 13 bullets); p. 6-57 (4th paragraph); p. 6-59 (2nd paragraph). P. 6-60 (1st paragraph). Olsen Deposition testimony (9/10/08; p. 220).
[109] Olsen (2008a). p. 6-59 to 6-60
[110] Olsen (2008a). p. 6-62 (line 5).

## 3.4 High Flow Sample Stations

As discussed in Section 2.3.1, Olsen's spatial analysis discussion relied in large part on results from two high-flow sampling stations in areas of low poultry house density: HFS28A and HFS30. I pointed out that these two stations represent only a fraction of the high-flow samples included in Olsen's PCA. Pointing to Figure 2-5, I noted that there were numerous instances of red-dots (supposedly poultry impacted) plotting in green sub-basins (areas of low poultry house density), and that this suggests that Olsen's spatial analysis is not as consistent with his poultry-impact classification as he might have us believe. In this section, I will present a more detailed review of some of the high-flow-station data that contradict Olsen's interpretation.

Figure 3-12 shows the location of high flow sample station HFS-05. Twenty high flow samples were collected from this station, between June 2005 and June 2006. For Olsen's SW3 PCA run, The PC1 scores for all 20 samples exceeded 1.3. The average PC1 score was 1.52, and the maximum was 2.22. But this map shows that it is located at or near the downstream boundary of a zero poultry house density sub-basin. This sub-basin is located just west of Fayetteville, Arkansas (the largest city in the IRW – see inset map). To the extent that Olsen's PC1 scores reflect contamination, it would certainly seem that urban runoff would be a more plausible explanation for the water quality at the HFS-05 sample station.

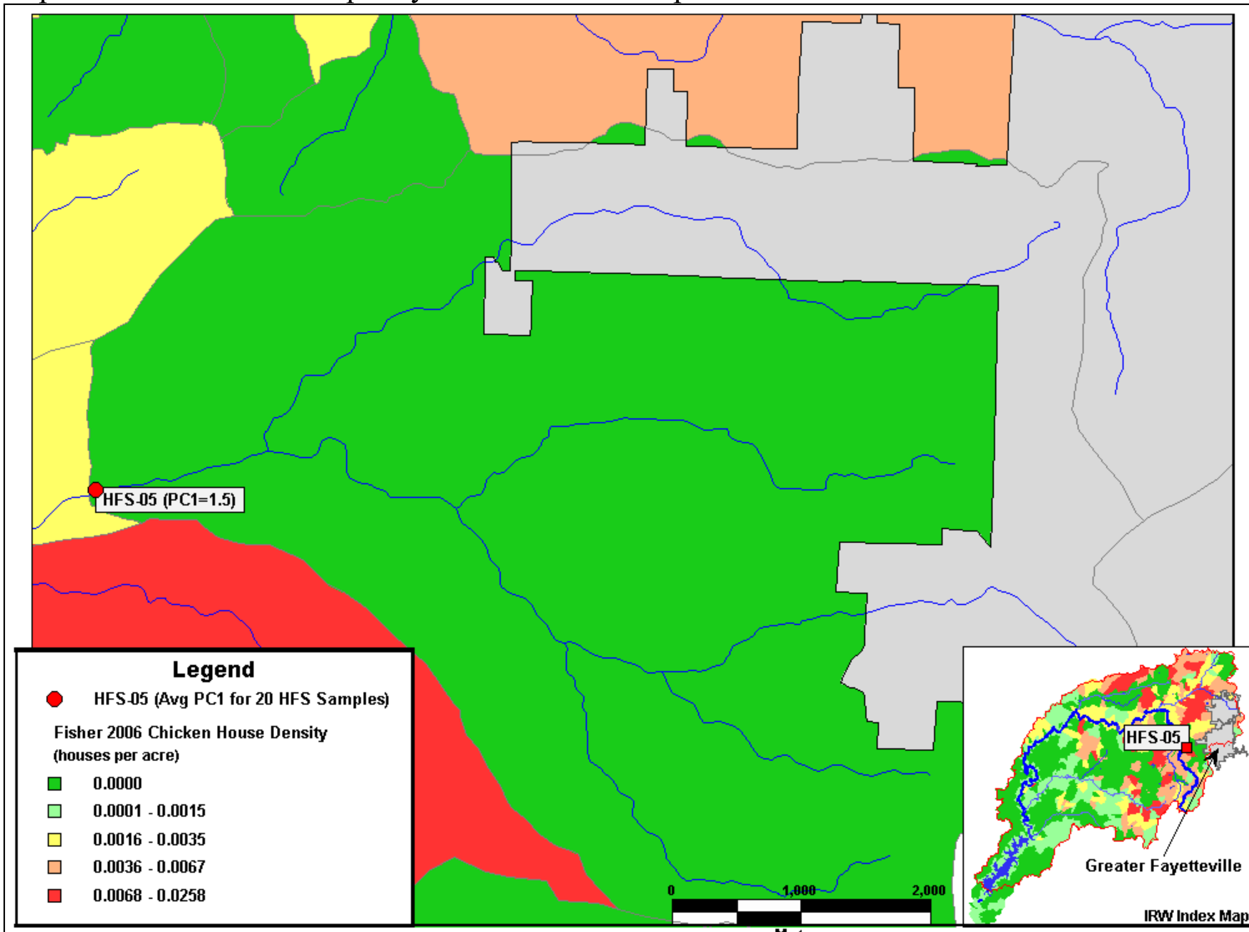


**Figure 3-12.** Location of HFS-05 plotted over Olsen poultry house density data and greater Fayetteville Area (gray shaded area).

A second example is HFS-22 near Lincoln, Arkansas. Figure 3-13 shows its location at the downstream edge of a zero poultry-house density area. This is the same area where Olsen collected his Lincoln WWTP sample (Section 3.2) and that sample is shown on Figure 3-13 along with HFS-22. Fifteen high-flow samples were collected at HFS-22 between May 2005 and May 2006. All but one yielded PC1 scores greater than 1.3 (average=1.64 | range: 1.24 to 2.00). Like Olsen's "Lincoln WWTP" sample, HFS-22 is located downstream of both the city of Lincoln and its sewage treatment plant (POTW outfall - Figure 3-13).

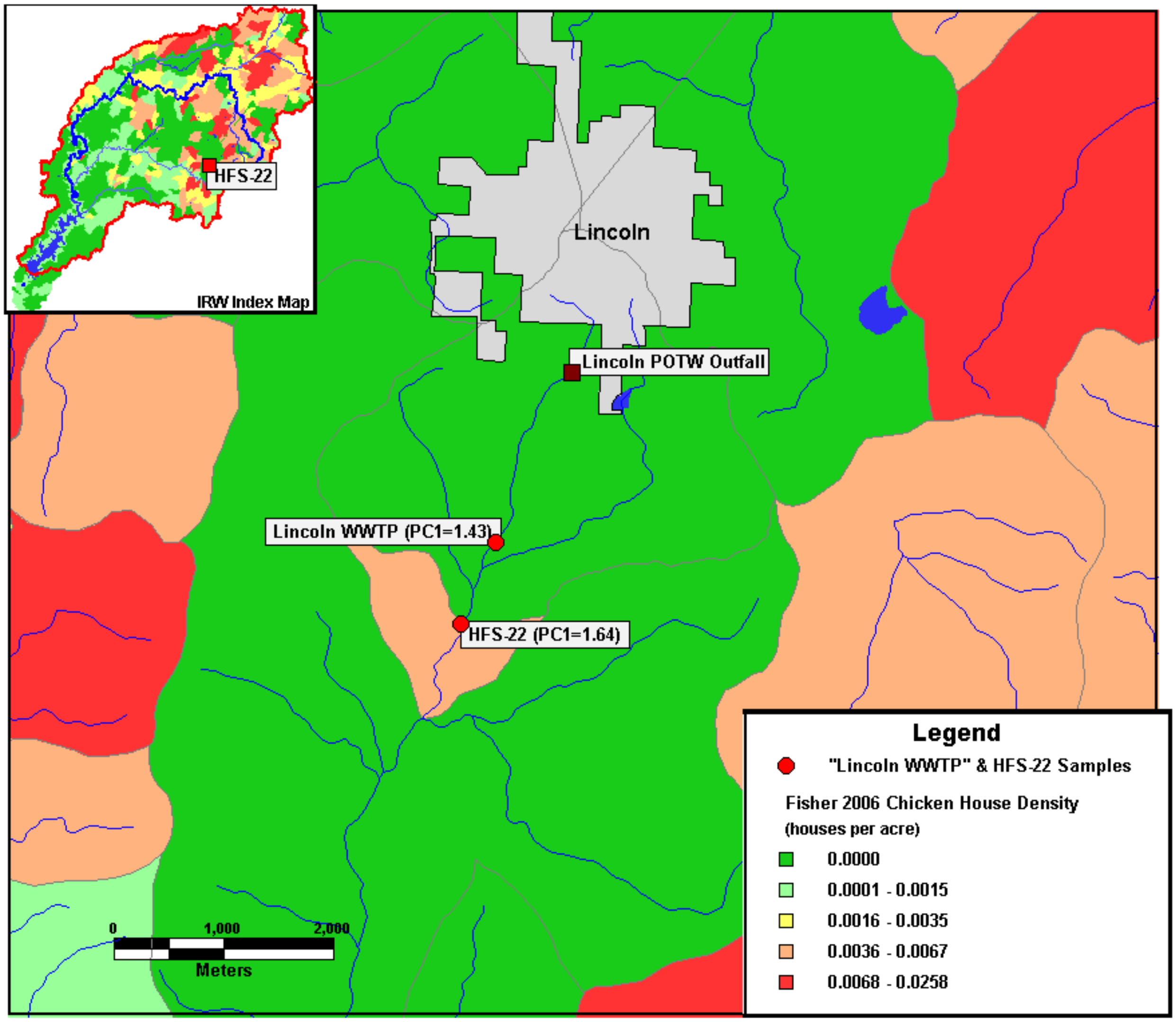


**Figure 3-13.** Locations of HFS-22 and Lincoln WWTP samples, plotted over Olsen poultry-house density data.

PC1 score shown for HFS-22 is the average of 15 high-flow samples collected at this location.

To the extent that Olsen's PC1 scores reflect contamination, his spatial analysis suggests that urban runoff and/or WWTP impacts are more plausible explanations. Elsewhere in his report, Olsen acknowledges this. In his discussion of sources of phosphorus in context of poultry house density, Olsen acknowledged that HFS-22 was sampled to provide information on the mass loads contributed by this type of WWTP facility. In the same discussion, he indicated that HFS-22 was excluded from the phosphorus statistical analysis because the stream water quality at this site is dominated by effluent from the Lincoln wastewater treatment plant.[111] These cautions and caveats were apparently not taken into consideration in the spatial analysis performed in support

[111] Olsen (2008a). p. 6-29. Final paragraph.

of Olsen's PCA interpretation. While acknowledging that this sample is dominated by wastewater treatment plant effluent, and aware that it is located in a low poultry-house density area, it did not influence his choice of a 1.3 PC1 poultry-impact threshold. This illustrates both the internal inconsistency in Olsen's report, and the arbitrary nature of his *'unique poultry waste signature'* criterion.

The third and fourth examples (HFS-04 and RS-336) are in or downstream of Siloam Springs, Arkansas (Figure 3-14). Both are located on Sager Creek, and both are located within a sub-basin that Olsen's data shows as having zero poultry house density.

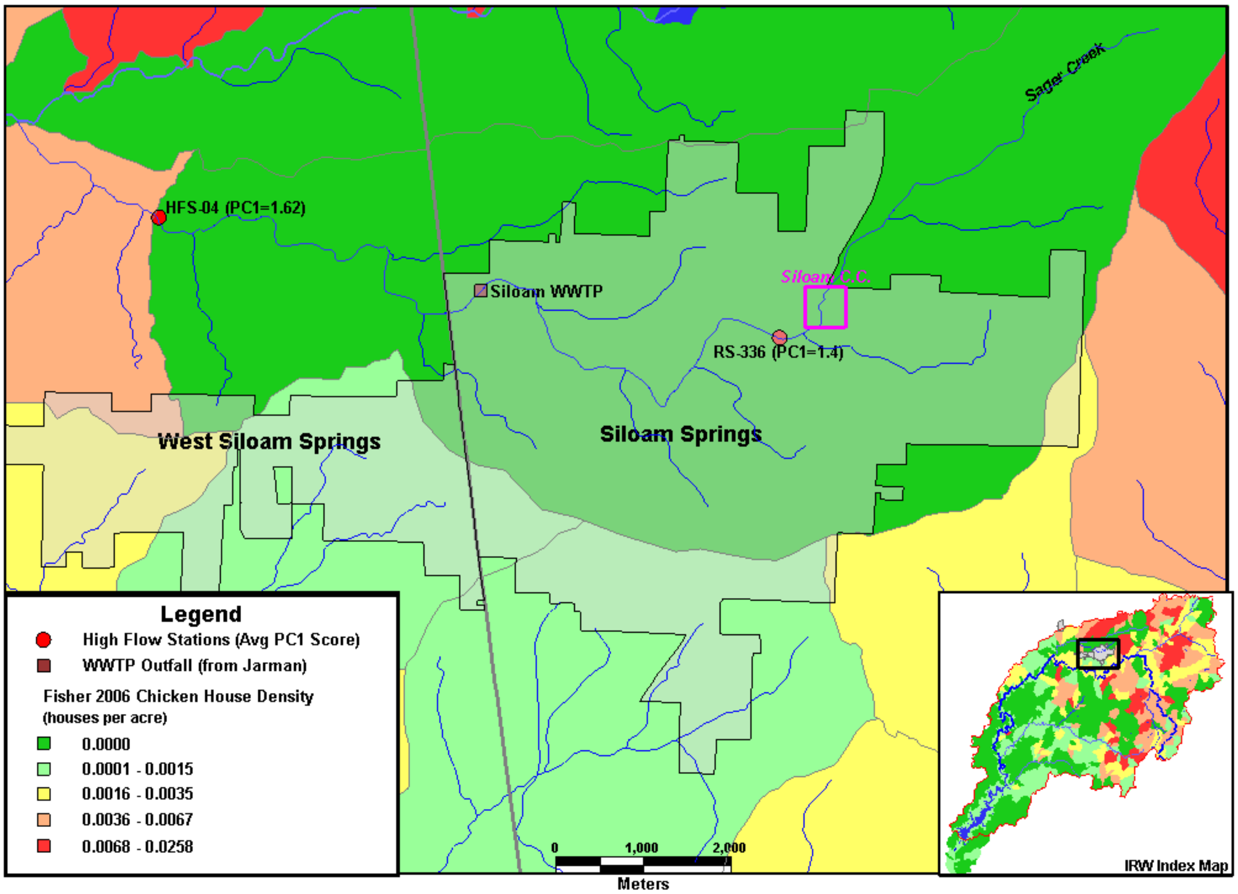


**Figure 3-14.** Siloam Springs high-flow samples plotted over poultry-house density.
Also shown: (1) Location of Siloam Springs WWTP; (2) Location of Siloam Springs Country Club (golf course); (3) city limits of Siloam Spring, Arkansas and West Siloam Springs, Oklahoma, based on ESRI (2006) data.

Nineteen samples were collected from high-flow sample station HFS-04 between May 2005 and May 2006. All 19 yielded PC1 scores greater than 1.3 (average=1.62 | range is 1.48 to 1.73). Like the Lincoln sample, HFS-04 is located downstream of both the city of Siloam Springs and its waste-water treatment plant (Figure 3-14). Once again, to the extent that Olsen's PC1 scores reflect contamination, his spatial analysis suggests that urban runoff and/or WWTP impacts are more plausible explanations. Once again, Olsen acknowledged this elsewhere in his report. In the same discussion of HFS-22 (in context of phosphorus concentrations and poultry house density, as discussed above) Olsen indicated that HFS-04 was excluded from the phosphorus statistical analysis because the stream water quality at this site is "*dominated by effluent from the City of Siloam Springs wastewater treatment plant.*"[112] This was apparently not taken into

[112] Olsen (2008a). p. 6-29. Final paragraph.

account in context of Olsen's PCA. Rather, HFS-04 was classified by Olsen as poultry-impacted and plotted as a red-dot on his red-dot / green-dot map. This contradiction, as revealed by this spatial analysis did not influence his choice of a 1.3 PC1 poultry-impact threshold. Once again, this illustrates both the internal inconsistency in Olsen's report, and the arbitrary nature of his '*unique poultry waste signature'* criterion.

The fourth example is shown on this same map. RS-336 is located within the city limits of Siloam Springs, within the same zero poultry house density sub-basin as HFS-04. Only one high-flow sample was collected at RS-336 (5/10/2007), but it yielded a PC1 score of 1.4. This sample-station is located immediately downstream of a golf-course (Siloam Springs Country Club). To the extent that Olsen's PC1 scores reflect contamination, it would seem that urban runoff and/or fertilizer application would be a more plausible explanation.

In summary, Olsen's discussion of his spatial analysis cites 15 high-flow samples collected from 2 sample stations located in areas of low poultry house density. Those samples yielded average PC1 scores below or near or his 1.3 threshold, and that was cited by Olsen as a line of evidence in support of his purported *unique poultry waste signature* criterion. In this section of my report, I have presented data from 45 high flow samples, collected at 4 locations. Using the same spatial analysis criteria as Olsen (locations with respect to urban areas, locations with respect to WWTPs, and the Olsen/Fisher poultry house density data) it is clear that his 1.3 criteria is not supported by his own data.

## 3.5 Base Flow Sample Stations

If we look at base-flow samples in relation to Olsen's poultry house density data we see a similar pattern, or lack thereof. Figure 3-15 shows numerous red-dots plotting in green sub-basins.

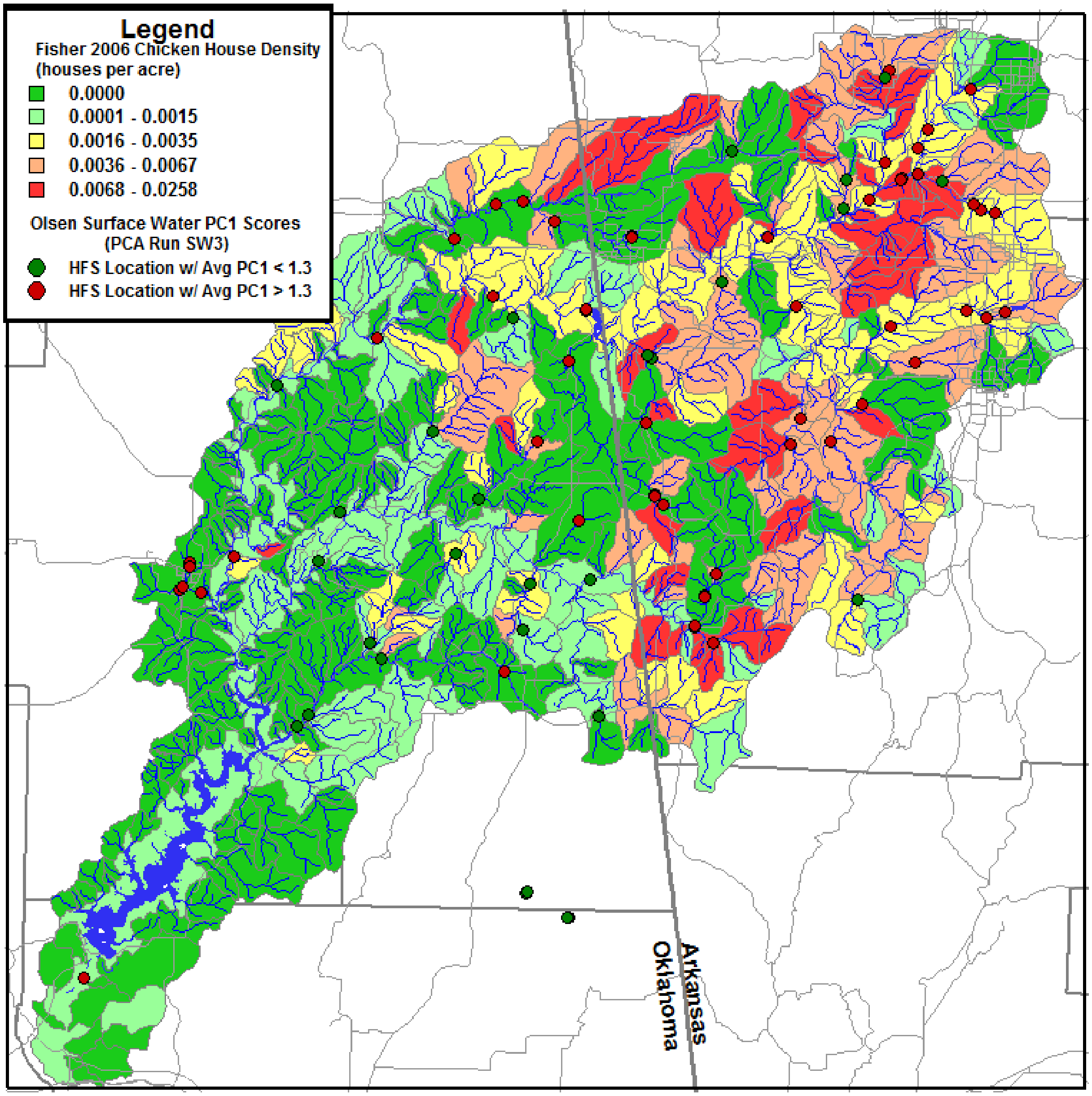


**Figure 3-15.** Base-flow sample PC1 scores map, plotted over poultry house density data.

However, if we plot these same base-flow results over a map showing human population centers, we see a more consistent pattern (Figure 3-16). Many of the red-dots that are anomalous with respect to poultry-house density data (Figure 3-15) are located in and immediately downstream of cities, towns, and/or WWTPs. This is particularly evident in streams that drain the greater Fayetteville/Bentonville urban areas. But it is also apparent in base-flow samples downstream of Siloam Springs, Tahlequah,[113] Stillwell, Watts, Prairie Grove, Westville, and Lincoln.

[113] Note that the Tahlequah base-flow samples shown on Figure 3-16 are the same samples that Olsen changed on his red-dot / green-dot map (Section 3.1). The coincidence of red-dots and urban areas for base-flow samples provides a plausible explanation for why the Tahlequah data did not fit Olsen's theory.

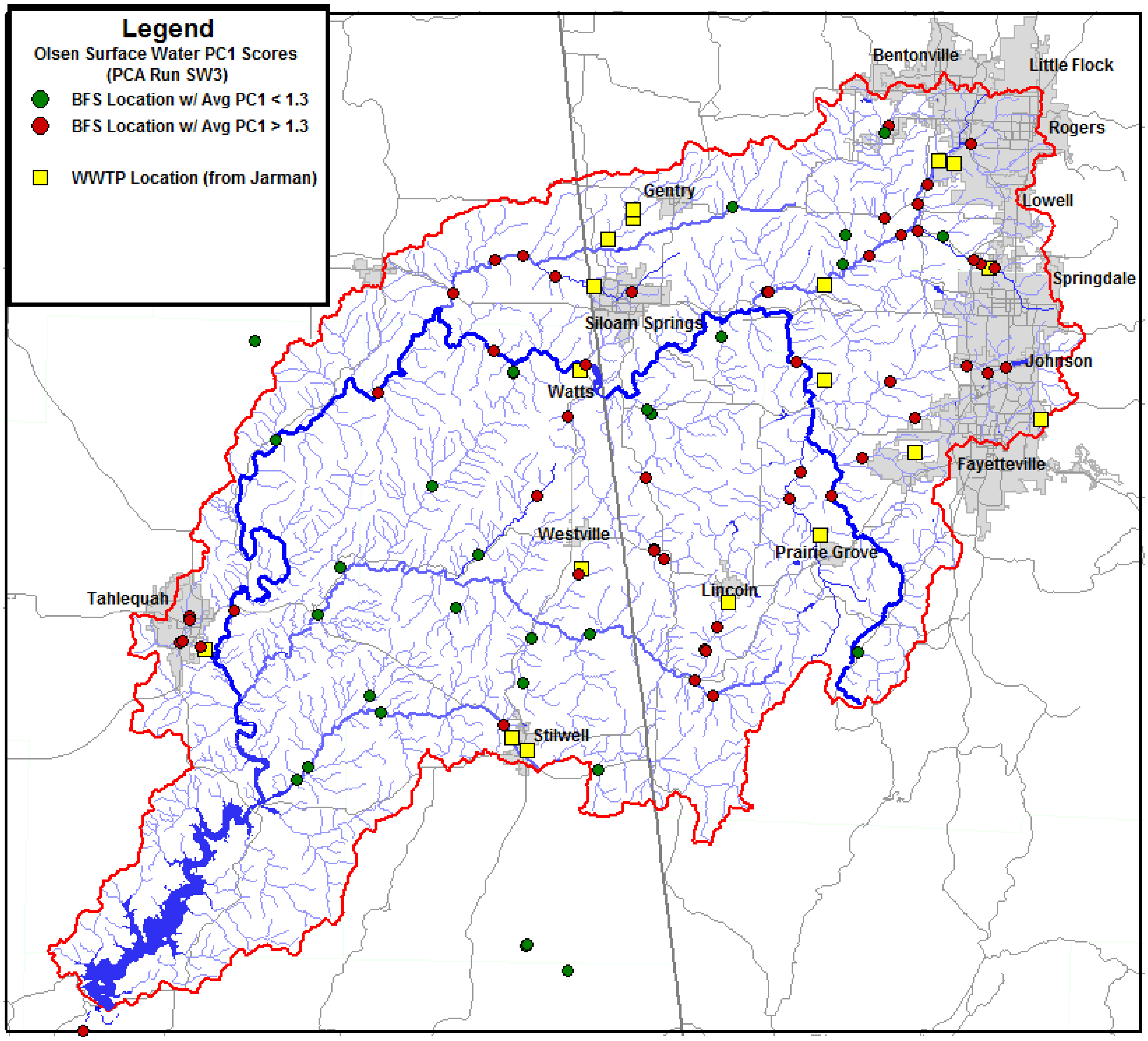


**Figure 3-16.** Base-flow PC1 scores map, plotted with respect to urban areas and WWTP Locations Olsen's PC1 threshold plotted over basemap showing areas of high human population density and WWTP locations WWTP locations from Jarman, personal communication. Gray shaded areas indicate regions of human population density > 400 people/mi$^2$, based on ESRI (2006) data.

This map and its comparison to Figure 3-15 (same PCA results plotted over poultry-house density data) makes it clear that Olsen's 1.3 PC1 criterion for a '*unique poultry-specific biological and chemical signature'* is neither unique nor poultry-specific. Whatever is driving PC1 (see alternative interpretation: Section 4.2) it is in large part coming from areas of high human population, in absence of poultry.

# 4.0 Alternative Interpretation of Olsen's PCA

As discussed in Sections 2.0 and 3.0, there are major problems and inconsistencies with Olsen's PCA. The data simply do not support his interpretations. In this section, I present alternative interpretations/explanations of Olsen's PCA.

## 4.1 An Alternative PC1 Poultry-Impact Threshold

It is my opinion that Olsen's 1.3 PC1 criterion is arbitrary, and that there is no PC1 threshold that can be applied as an indicator of poultry-impact because PC1 does not equal poultry. But in the end, making such an argument is hardly necessary. Taking Olsen's interpretation at face value, a critical review shows contradictions at every turn. SW3 included a number of samples collected to characterize sources other than poultry (cattle edge-of-field; WWTP and Tahlequah), and every single one of them yielded PC1 scores greater than 1.3 (Section 3.1, 3.2 and 3.3). In addition there were many high-flow and base-flow stream samples that are contradicted by Olsen's spatial analysis (Sections 3.4 and 3.5).

But what would happen if Olsen had tried to preserve his opinion that PC1 equals '*poultry waste impact*', and just changed the PC1 threshold to a value better supported by the spatial analysis. The first step would be to define a more reasonable threshold. If we were to just move the PC1 threshold up to a value greater than that observed for the samples that contradict Olsen's opinion, it would be both reasonable and '*conservative.*'[114] What's more, Olsen would not have had to veto PCA results or speculate about potential poultry litter application in cow-pastures or wastewater treatment plants. This would alleviate many problems for Olsen.

The maximum PC1 score for cattle edge-of-field; WWTP and Tahlequah samples was 2.11 (sample EOF-CP1B). A PC1 threshold of 2.12 would be conservative in that it would exceed the PC1 scores for all of these samples (Figure 4-1).

[114] Olsen repeatedly claims to have been '*conservative*' in establishing his 1.3 threshold. See Olsen 2008a: p. 6-60 (1st paragraph); Olsen Deposition, 9/10/08 pp. 218 (line 14) to 219 (line 6); Olsen Deposition, 9/10/08 p. 222 (Lines 3-12); Olsen Deposition, 9/11/08 pp. 330 (line 24) to -332 (line 5); Olsen Deposition, 9/11/08 pp. 472 (line 3-17). Olsen Deposition, 9/11/08 pp. 484 (line 5-8). Olsen Deposition, 9/11/08 pp. 485 (line 8-24).

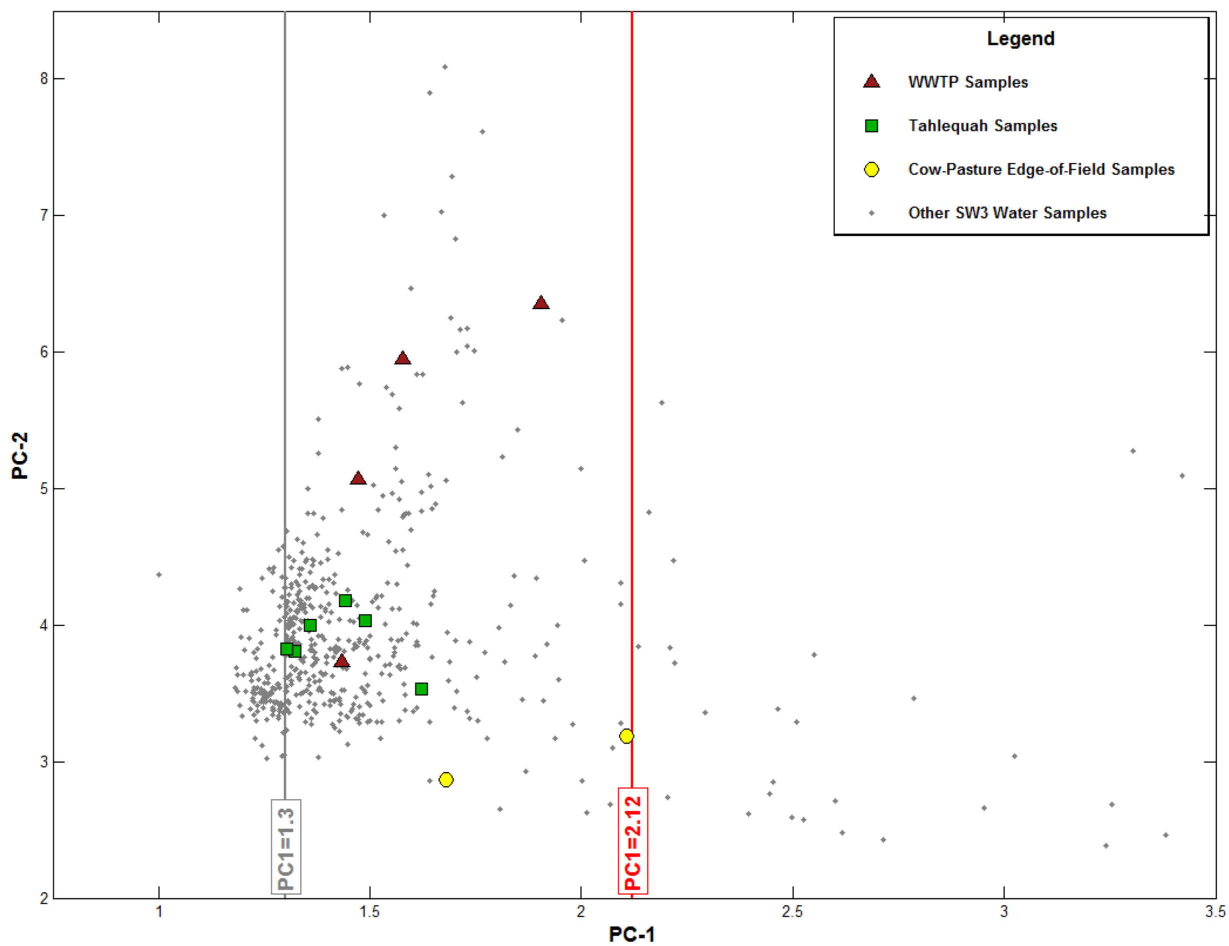


**Figure 4-1.** SW3 scores plot with known, non-poultry impacted samples highlighted.

Given this new threshold, Olsen's red-dot / green-dot map would be as shown on Figure 4-2. Looking at these results in context of a spatial analysis, this would seem to solve a lot of problems for Olsen. The three reference stream locations and two high flow locations cited in his spatial analysis discussion[115] are well below 2.12, so this more conservative PC1 threshold still supports the argument that appears in his report. The 2.12 threshold is in fact better, because Olsen doesn't have to round HFS-30 PC1 score down from 1.3022 to 1.3 to support his argument (see Figure 2-5). All Tahlequah scores are below the 2.12 threshold, so there is no need to make the subjective decision to veto his PCA results, and manually change the color of the Tahlequah sample from red-dots to green-dots. All WWTP effluent samples exhibit PC1 scores <2.12, so there is no need to veto those results either. The two EOF-CP samples are below a 2.12 threshold, so there is no need to speculate about poultry impact in cow pastures that reportedly have never had poultry litter applied to them. In addition, we no longer see as many red-dots plotted for samples down-stream of urban areas with low poultry-house density (Lincoln, Westville, Rogers, Fayetteville). A 2.12 PC1 threshold would to make for a simpler, more lucid story, without Olsen having to abandon his theory that PC1 equals poultry.

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[115] Olsen (2008a). p. 6-59 to 6-60.

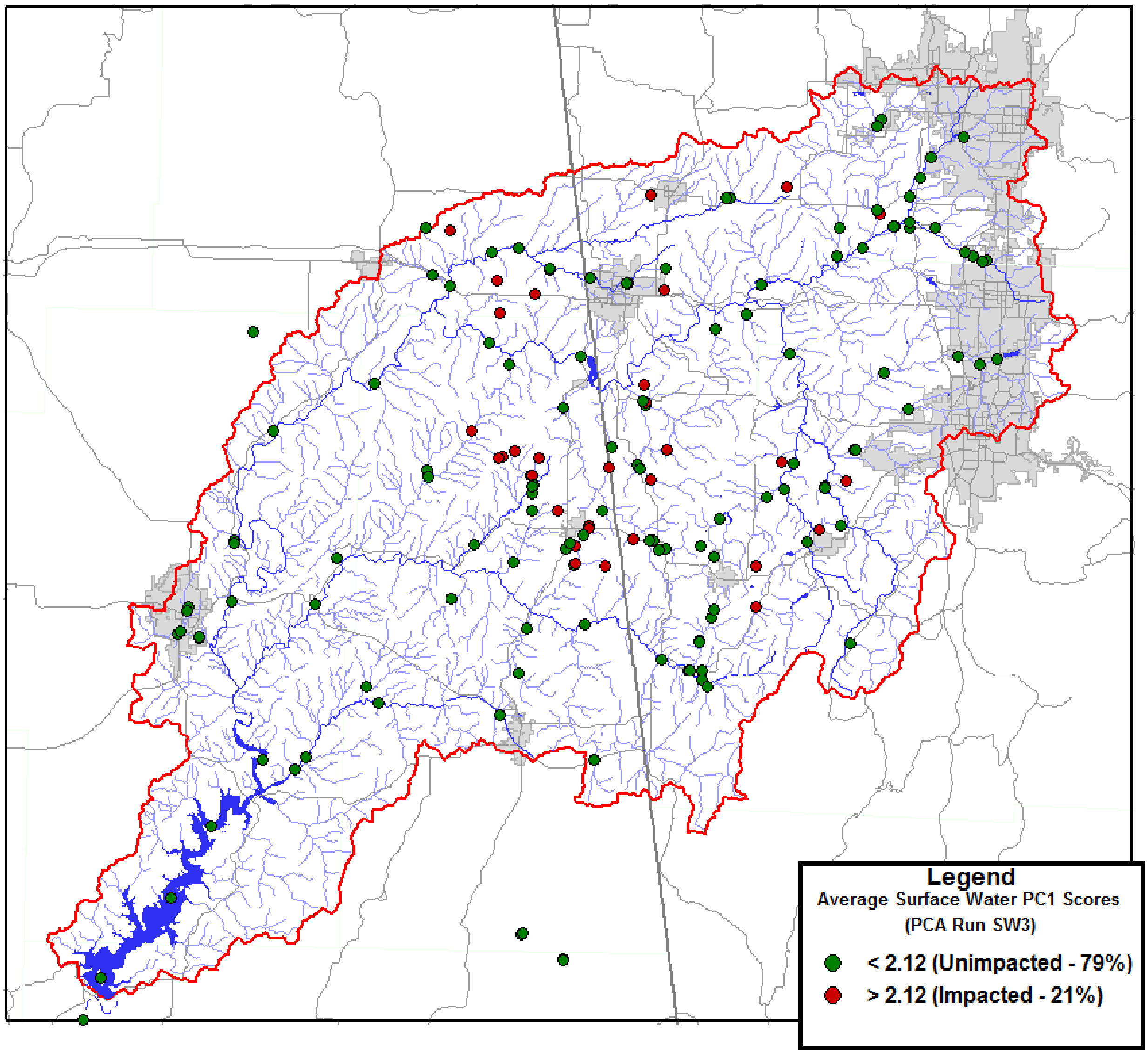


**Figure 4-2.** Olsen's red-dot / green-dot map using a PC1 threshold of 2.2.

However, this threshold yields a very different estimate of water samples supposedly impacted by poultry. Seventy-nine percent (79%) of IRW sample stations would now be classified by as unimpacted by poultry, and plot as green dots (Figure 4-2). Of that 21%, only one sample (SN-SBC2) is a river, stream or lake water sample. In other words, all but one of the red-dots on Figure 4-2 are edge-of-field samples. What's more, even that single stream sample with a PC1 score greater than 2.12 does not support the theory of a poultry source. A map showing the location of SN-SBC2 is provided as Figure 4-3. It is located in an area of low poultry house density, less than 500 meters downstream of the Westville WWTP.

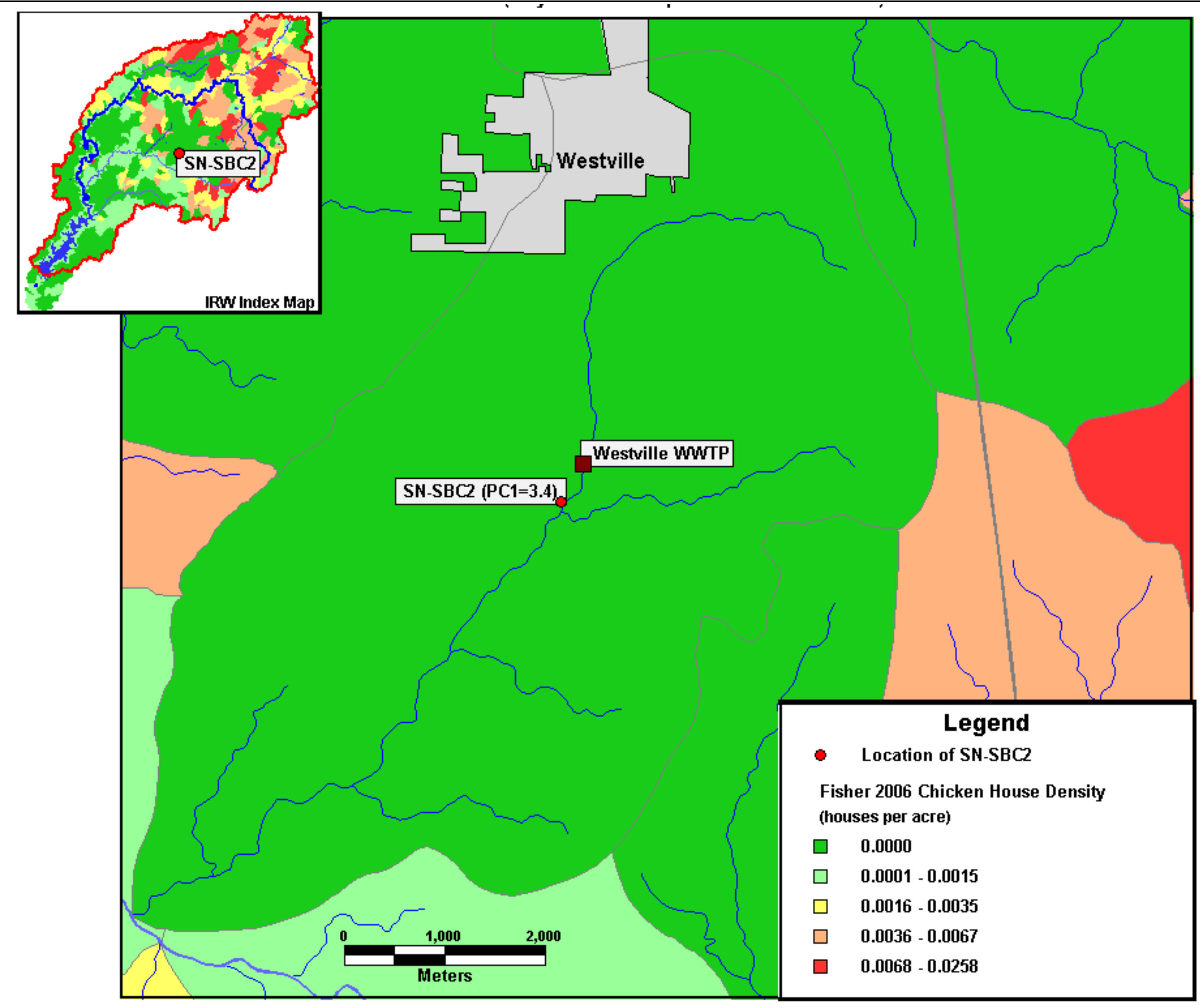


**Figure 4-3.** Location of SN-SBC2, in relation to poultry house density data and Westville WWTP.

This exercise shows that even if you overlook issues of faulty assumption and errors in implementation, accept at face-value Olsen's PCA interpretation that PC-1 equals poultry, and try to salvage the theory with a more reasonable threshold, the inevitable conclusion is still that Olsen's PCA does not support an opinion that "*poultry waste is by far the dominant contamination source in the IRW.*"[116] Olsen could not propose a more realistic PC1 threshold without simultaneously concluding minimal poultry impact to surface waters of the IRW.

## 4.2 PCA Interpretation In Context of Concentration and Differential Partitioning.

In Section A2.2 of Appendix A, I pointed out that Olsen did not do a transformation to normalize out the effect of widely differing concentrations. I also pointed out that, as a result, I would expect that the total concentration of samples would exert tremendous influence on where samples plotted on a scores plot. This turns out to be the case. To show this, I have re-plotted Olsen's SW3 scores plot, with colors assigned to symbols as a function of the sum concentration for all chemical variables (Figure 4-4). Bacteria was omitted from this sum for several reasons:

[116] Olsen (2008a). p. 1-2. Bullet 3.

(1) bacteria were reported in different units (org/100ml rather than mg/L); (2) bacteria data were missing from more than a quarter of the samples in SW3 (Appendix A: Section A2.1); and (3) bacteria has essentially no predictive ability in this PCA model whatsoever (See Appendix A, Section A2.4 & Figure A-5).

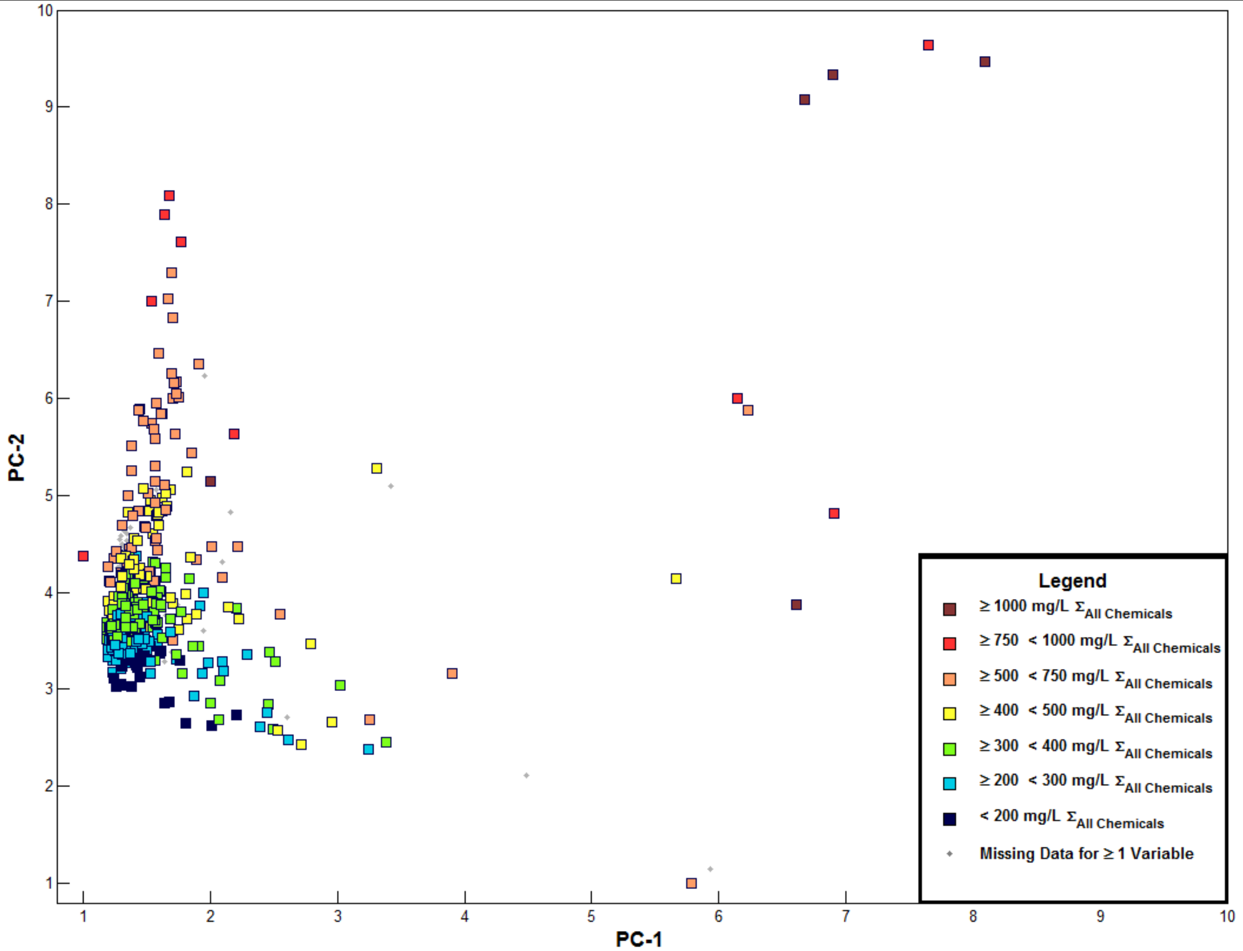


**Figure 4-4.** SW3 scores plot with symbol colors plotted as a function of total concentration.

The pattern here is exactly what we would expect from a PCA where no sample-normalization was done. Sample scores are strongly controlled by total concentration. Low-concentration samples (blue squares) plot at the bottom left corner of the data cloud (the corner of the "L"). As you move away from that corner of the scores plot, samples increase in total concentration, transitioning from blue to hotter colors: yellow, orange, red, and then brown. In general, a PCA scores plot that shows a "V" or "L" shaped data cloud is a tell-tale sign that the PCA did not include a transformation to normalize out concentration.

It is also clear on this plot that the greatest density of samples is along one of two trends: (1) along the bottom of the L; and (2) along the left side of the L. These two trends are labeled on Figure 4-5, below. A few samples do not plot within one of these two trends (e.g. samples plotting to the extreme upper-right), but these exceptions are primarily edge-of-field samples. The vast majority of IRW stream and lake surface-water samples plot within one of these two trends.

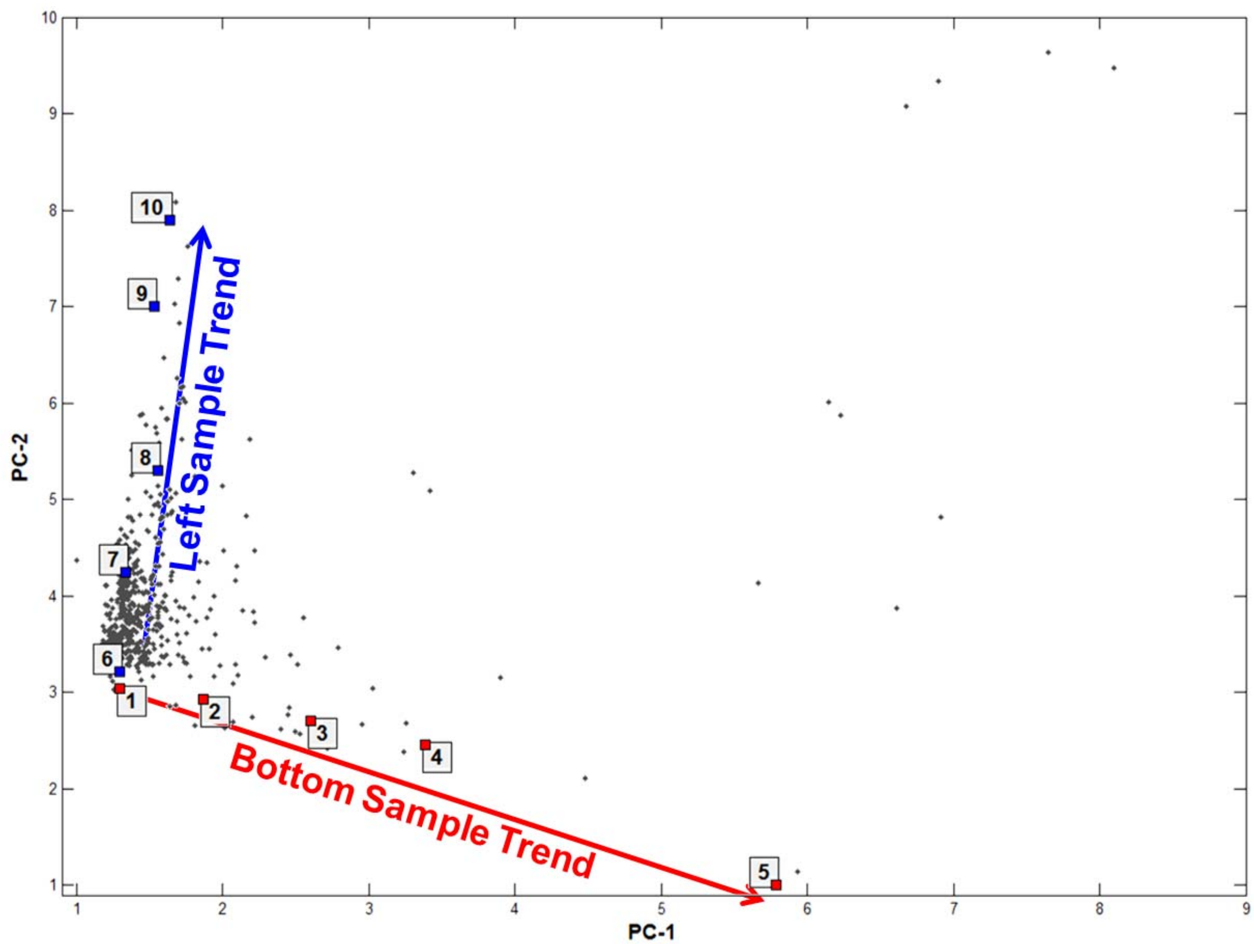


**Figure 4-5.** SW3 scores plot showing samples along bottom trend (red) and left trend (blue). Numbered samples are shown as bar-graphs on Figures 4-6 and 4-9.

Note on Figure 4-5 that there are numbered samples along each of these two trends. Samples 1 through 5 are shown along the bottom trend as red squares. Samples 6 through 10 are shown along the left trend as blue squares. Bar-graphs for the five samples along the bottom trend (red) are shown on Figure 4-6. Several observations can be made with regard to these five samples. First, note the bacteria data on the far right. All bacteria data were missing from the two lowest concentration samples (samples 1 and 2). The gray bars indicate missing data, and the height of the bars represents the mean (average) concentrations that were substituted for missing data. There is wide variation in bacteria concentrations and no discernable trend or pattern is observed as one moves to the right along the bottom sample trend.

Note also, that the three variables highlighted by pastel red shading: total phosphorus ($P_T$), total iron ($FE_T$) and total aluminum ($AL_T$) increase in concentration as you move to the right along the bottom trend. Iron and aluminum are not as soluble as ions such as sodium and chloride. As such, Fe and Al are generally associated with suspended sediment fraction of natural waters. Sorption of phosphorous to suspended particulate matter is common, with phosphate ions taken up from water by alumina, clay particles, and freshly precipitated iron and aluminum hydroxides (Stumm and Morgan, 1970). As such, particulate-bound phosphorus constitutes much of the phosphorus in runoff from cultivated land (Sharpley and Smith, 1990). As a result, total phosphorous in natural waters has been observed to correlate with total suspended solids (TSS - Sullivan, et. al., 2005).

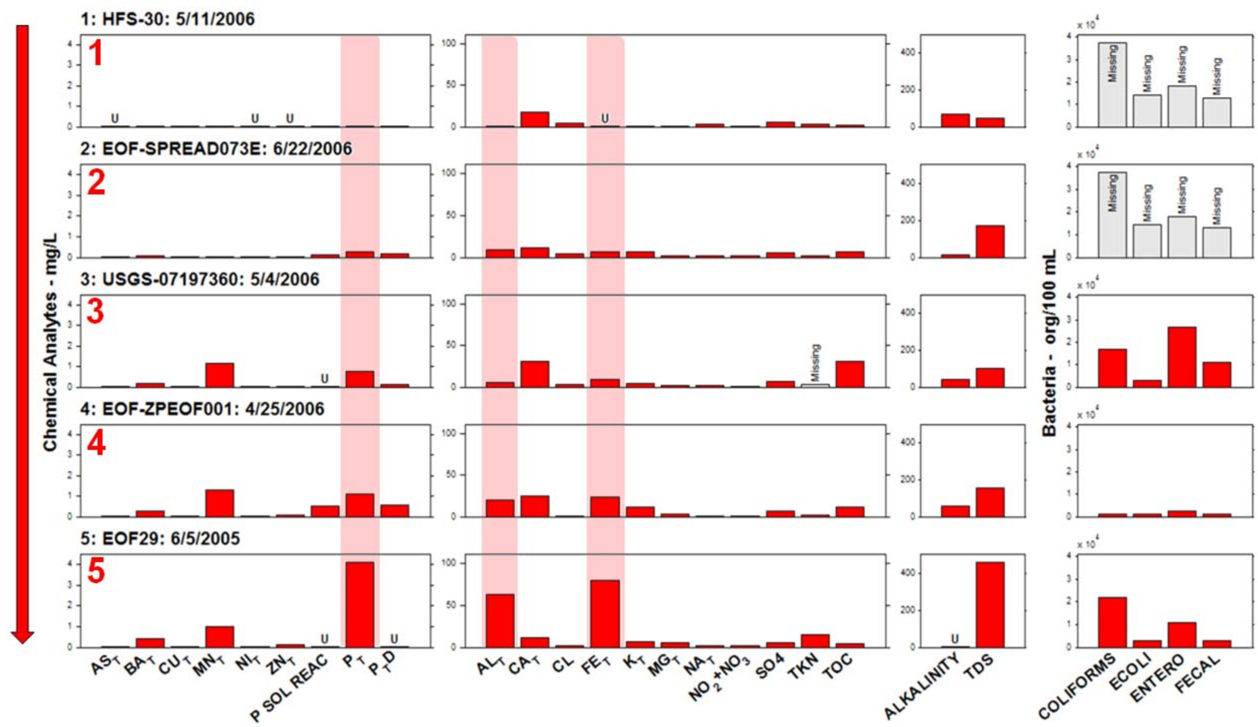


**Figure 4-6.** Bar graphs for the five bottom-trend samples indicated on Figure 4-5.

These observations suggests that the 'bottom trend' on Olsen's SW3 scores plot is associated with TSS, and that total phosphorous increases along this trend as a function of its association with suspended particulate matter.

But, the bar-graph above represents only five samples. If this interpretation is true, we should see increasing Fe and Al concentrations in all samples along this trend. Figure 4-7 shows Olsen's SW3 scores plot, with the symbol-color keyed to the concentration of total iron plus total aluminum. The trend suggested by the five samples discussed above, is observed for the data set as a whole. The concentration of total iron + total aluminum increases in samples along the bottom trend of Olsen's SW3 scores plot.

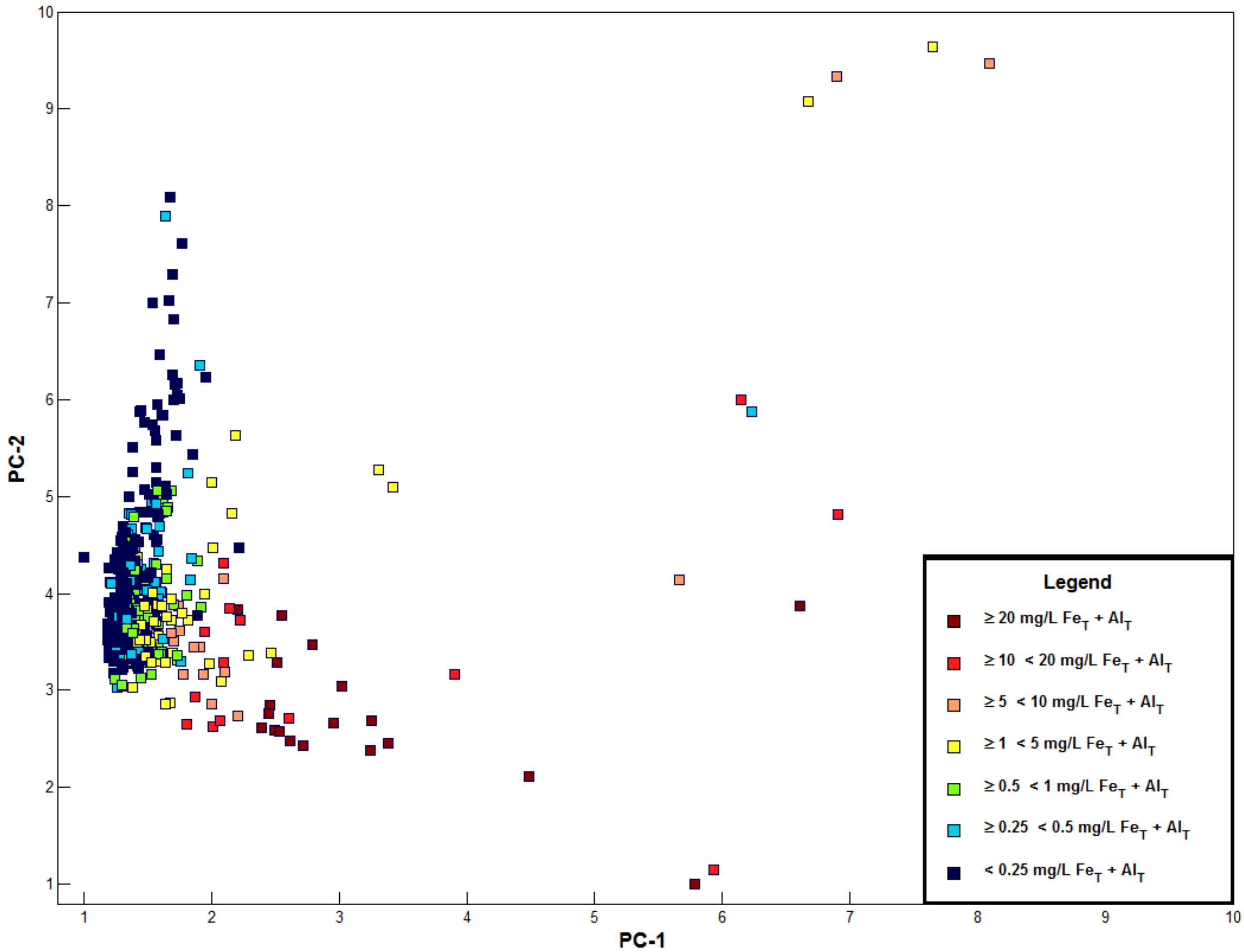


**Figure 4-7.** Olsen's SW3 scores plot, with symbol colors reflecting total Iron + total Aluminum.

If the sum of total iron and total aluminum reflects suspended sediment, then plotting PCA scores as a function of total suspended solids (TSS) should show a similar pattern. TSS was not included as a variable in Olsen's PCA, but it was provided in Olsen's database.[117] Figure 4-8 shows Olsen's SW3 scores plot, with the data plotted as a function of reported TSS concentrations. We see the same pattern that we saw for iron + aluminum. As you move from left to right across the bottom trend of Olsen's SW3 scores plot, TSS increases in concentration.

Clearly one of the major controls on Olsen's SW3 PCA run is the degree to which a water sample has high concentrations of suspended sediment. Samples that plot along this trend do so as a function of turbidity and suspended sediment, not poultry impact. In addition, consider that the muddier a water sample is, the higher the suspended sediment concentration will be. To the extent that edge-of-field samples exhibit high PC1 scores, it reflects preferential sampling of muddy water in EOF samples. This explains why Olsen could never get the cattle edge-of-field samples to "break out" from other edge of field samples: EOF samples would be expected to have high TSS, regardless of whether they are collected from a cow pasture, a road-side ditch, or a mud-puddle near a field where poultry litter might have been applied.

[117] TSS data are contained in the spreadsheet "PCA_Main_Database_Water.xls" within the worksheet 'Water (Out)'. TSS was included as an analyte for CDM/Lithochimia-collected samples, but not for USGS samples.

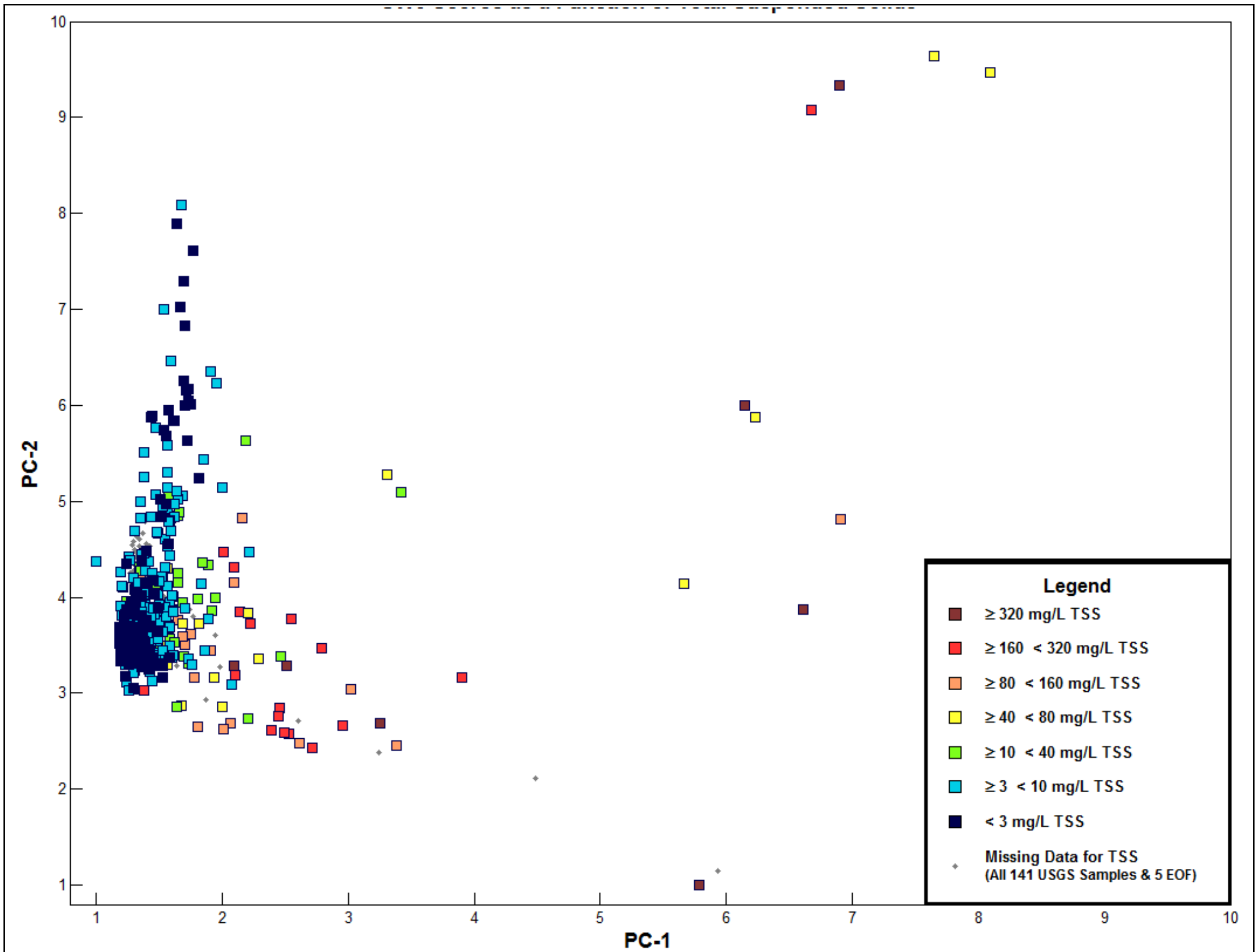


**Figure 4-8.** Olsen's SW3 scores plot, with symbol colors reflecting Total Suspended Solids (TSS).

None of this should come as a surprise to a geochemist, and it should not surprise Olsen. The following testimony came in context of a line of questioning related to the potential effects of stream-bank erosion (i.e. an input of suspended sediments) on Olsen's analysis:

> ***Q*** *What would you have expected to have seen in terms of a different composition?*
> ***A*** *You know, stream banks would have had more iron, more aluminum, you know, generally more highly elements that are in the sediments.*
> ***Q*** *Okay.*
> ***A*** *More silica. You know, we didn't analyze for silica. So more iron, more aluminum. We would have seen those types of things.*
> ***Q*** *Did you evaluate those samples for iron and aluminum concentrations to determine whether stream impact -- I'm sorry, stream bank erosion may be having an effect on those samples?*
> ***A*** *That was all in the principal component analysis, so it would have related to a change in chemical composition that in my opinion you would have been able to see if it was major.* [118]

In this quote, Olsen acknowledges that iron and aluminum are preferentially associated with suspended sediment in water. He says that if suspended sediment were a controlling factor, we would have seen it in his PCA results. We do see it in his PCA. Olsen just failed to recognize it. Clearly, suspended sediment, iron and aluminum exert a strong control on total phosphorus, and in turn on where samples plot on Olsen's SW3 scores plot.

[118] Olsen Deposition. 9/10/08. p. 77-78.

Going through the same process for the left trend (blue squares – samples 6 through 10 on Figure 4-5), the bar-graphs for these samples are shown on Figure 4-9. Again, the bacteria data exhibit a wide range of variability, with the highest values observed in otherwise low concentration samples, where missing data has been substituted.

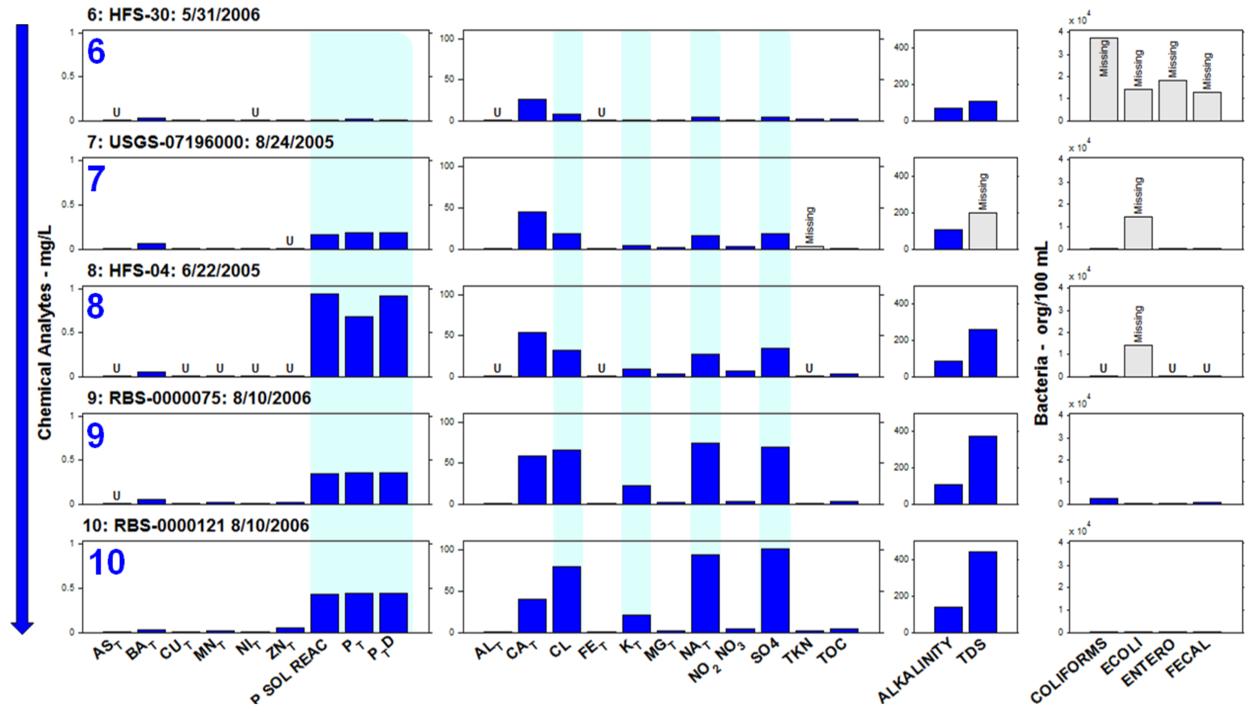


**Figure 4-9.** Bar graphs for the five left-trend samples indicated on Figure 4-5.

Variables shown with blue shading (total sodium ($NA_T$), total potassium ($K_T$), chloride (CL) and sulfate ($SO_4$)) all increase in concentration along this trend. These analytes are more soluble in water (Freeze and Cherry, 1979) so in contrast to iron and aluminum, they prefer to be in dissolved-phase rather than adsorbed to particulates. Once again, this should come as no surprise, and Olsen testified that for highly soluble analytes like sodium and potassium, the concentration reported as "total" should roughly equal their reported "dissolved" concentrations, because they are typically found entirely in solution.[119]

Note that all of these samples have low iron, aluminum and TSS (Figure 4-5 and 4-8). Note also that the two soluble forms of phosphorus ($P_TD$ and P_SOL_REAC) are close to equal in each sample and are also close to the reported concentrations of total phosphorus. This suggests that the general increase in P concentrations in these samples (sample 8 being the exception) reflects dissolved phase phosphorus, rather than particle-bound phosphorus.

As for the bottom trend, I picked just five samples to show on Figure 4-9. Figure 4-10 shows Olsen's SW3 scores plot, with the symbol color keyed to the concentration of $NA_T + K_T + Cl + SO_4$. The trend observed in the bar-graphs above, is evident for the data set as a whole. The concentration of highly soluble analytes increases as you move up along the left trend of Olsen's SW3 scores plot. Clearly, the primary controls on Olsen's PCA are related to elementary geochemistry: whether an analyte is preferentially associated with the dissolved phase or particulate/suspended solids phase. To the extent Olsen's PCA model reflects real-world geochemistry, it is controlled by solution/adsorption processes, not sources.

[119] Olsen (2008a). p. 3-18. 4th paragraph. Olsen Deposition. 9/10/08. p. 116-117.

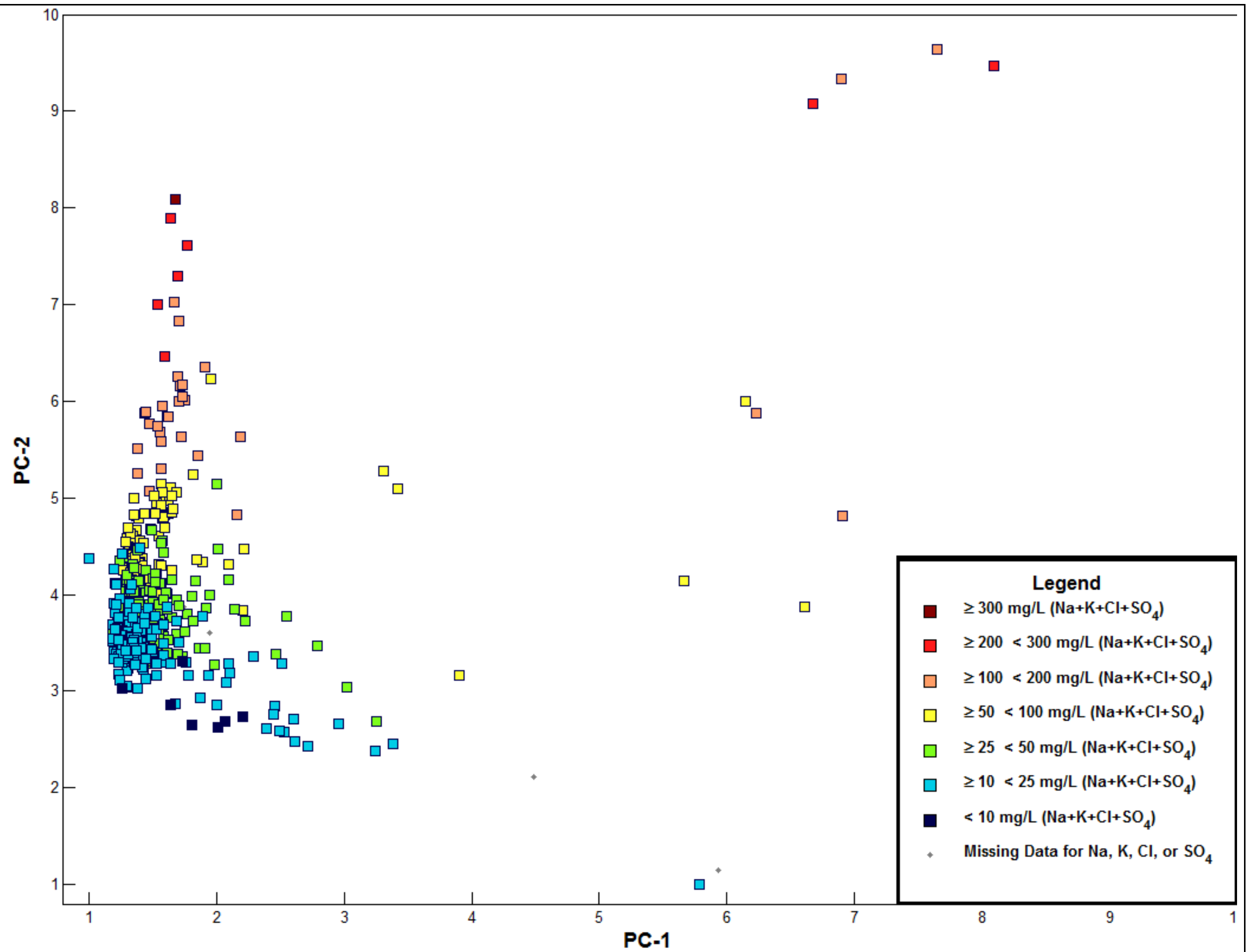


**Figure 4-10.** SW3 scores plot, with symbol colors reflecting concentration of highly soluble analytes (K, Na, Cl and $SO_4$).

Given this alternative interpretation of Olsen's PCA, let's revisit his interpretation and see how they compare. Olsen claimed that PC1 equals poultry, and that 1.3 is an appropriate threshold for delineating poultry-impacted versus non-impacted. But that theory had major problems. To explain away the contradictions, Olsen had to do one of three things: (1) ignore the contradictions (e.g. base-flow and high-flow samples that plot as red-dots in areas of zero poultry house density); (2) veto his own rule (e.g. Tahlequah, WWTP effluents) or (3) speculate about poultry impact in areas where there is no evidence of the application of poultry litter (e.g. cow-pasture edge-of-field samples). A simpler explanation is that PC1 does not *equal* poultry. As samples increase in PC1 scores, they do so as a function of suspended particulate matter. Regardless of the source (cattle, WWTP, poultry, soil erosion, contribution from urban sources like Tahlequah), total phosphorus and PC1 scores increase as a function of suspended sediment.

Olsen interpreted PC2 as WWTP effluent. PC2 does not *equal* anything, but the samples along the left trend (roughly parallel to PC2) generally increase in concentrations of water-soluble cations and anions (Na, K, Cl, and $SO_4$) as PC2 scores increase. As such, samples that plot within Olsen's "*WWTP-dominant impact*" area do so because they had high reported concentrations of soluble ions. Regardless of source, water samples with higher concentrations of dissolved salts will plot along this trend with high PC2 scores. This simple explanation alleviates the need to explain away anomalies like the majority of groundwater well samples in

SW17 exhibiting the "*WWTP fingerprint*" even though those wells are located nowhere near a waste-water treatment plant (See Section 2.3.2).

Once again, none of this should come as a surprise to Olsen. He is well aware that the samples he presumes to be '*poultry impacted'* have high TSS concentrations, and that samples presumed to be '*WWTP impacted*" have low TSS concentrations. In his report he stated that "*total suspended solids were found to be 10 to 100 times greater in the poultry EOF than in the WWTP*."[120] Olsen claims to have used PCA to discover unique chemical/biological signatures related to poultry and WWTP effluent. What he has actually discovered is nothing more profound than the distinction between muddy water and salty water.

[120] Olesen (2008a). p. 6-7 (2nd paragraph – lines 8-10) and 6-8 (1st paragraph – lines 9-11).

# 5.0 Summary and Conclusions

In the introduction of this report, I pointed out that Olsen cited a number of papers in the literature where PCA had been applied to environmental chemical data, but that the existence of such literature does not guarantee that its application to IRW will yield contaminant source signatures. Nor does it exonerate one from errors of implementation or misinterpretation of results. Nor does it justify concealing data/evidence that contradicted one's opinion. Olsen did all of this, and when one carefully dissects his analysis, it is clear that his PCA does not identify sources of contamination in the IRW.

PCA can be a useful tool in analysis of environmental chemical data, but there is no guarantee that the results will yield chemical fingerprints related to source. Its success in this regard depends on the analyst having a good understanding and sensitivity to the chemical system under study, the mathematics of the method, and its assumptions. There are numerous pitfalls for the unwary and inexperienced. In Olsen's application of PCA, he fell into a number of traps, many of which were identified in the literature, and cautioned against 20-30 years ago (e.g. reification of factors, interpretation of loading bar graphs as chemical compositions, and use of the percent-variance criterion for determining the number of significant principal components). Many of these pitfalls are errors of assumption. But Olsen also made errors in mechanical implementation of PCA, such as failure to do a sample normalization transformation, and incorrect back-calculation of scores.

Olsen also made an error in the basic philosophy of data analysis. PCA is considered a statistical method. But within statistics, there is a distinction between classical hypothesis testing methods and exploratory data analysis (EDA) methods. PCA falls in the latter category. In layman's terms, exploratory data analysis is more like detective work than hypothesis testing. One may reasonably carry a working hypothesis into an investigation, and Olsen clearly had his.[121] But the analyst must allow himself to be surprised by the data, and must entertain alternative theories if and when the data reveal the unexpected. Olsen did not do this. When faced with new data and/or PCA results that contradicted his theory of a predominant poultry source, his opinions did not change. Rather, the logic of his argument became more complicated (often to the point of sheer speculation) and/or new arguments were presented to fit the existing theory (e.g. cattle edge of field samples - Section 3.3). In the end, Olsen tells us that samples with PC1 scores less than 1.3 might be impacted by poultry, and he concedes that there are samples with PC1 scores greater than 1.3 are not impacted by poultry. He is left with a completely arbitrary poultry-impact threshold that can be vetoed when convenient.

But dissenting lines of evidence were not just dismissed or explained away, they were concealed. Olsen relied on a spatial analysis where he compared principal component scores to poultry house density data. He was clearly aware of contradictory results, but in a discussion of the spatial analysis, offered in support of his 1.3 PC1 threshold, he presented only a few examples that supported his theory. Contradictory results are not evident on Olsen's maps or score plots because of misleading annotation and/or use of data symbols that obscure the contradictions. In Tahlequah, Olsen made the subjective decision to override the PCA results, and changed the color of the Tahlequah samples to fit his theory. This was never disclosed in annotation of his map or in the text of his report. The four known cattle impacted samples in Olsen's analysis are classified as poultry impacted by his PCA (SW3 PC1 scores > 1.3) but the reader can't tell that

[121] From the time CDM began work on this project, the project has carried the acronym 'OPL' (Oklahoma Poultry Litigation), so it is clear what the initial working hypothesis was.

by looking at his score-plots, because Olsen used the same symbol to plot EOF-CP and all other edge-of-field samples. Olsen also never discussed in his report, that after multiple PCA runs had failed to show separation between presumed poultry and cattle impacted samples, he ran two PCAs with the explicit objective of getting separation between these two groups of samples. Those attempts failed, and the cattle argument that appears in Olsen's report mentions none of this. Instead, Olsen advanced a new argument (based on a different criterion) that somehow led to the same opinion expressed during the PI. Olsen's opinion never changes, only the argument necessary to explain new data.

Even in the absence of these errors, it is doubtful that a properly implemented PCA, applied to these data, would yield unambiguous results with regard to sources. One reason is data quality. Olsen collected 2,325 individual samples of the type included in his primary surface water PCA run. Only 267 (11.5%) had data for all 26 variables in Olsen's PCA run. Of these 26 variables, the four bacteria variables (total coliforms, E. coli, enterococcus, fecal coliform) were the most problematic: missing in 28 to 41 percent of samples in Olsen's PCA. The missing data substitution method employed by Olsen violates the assumptions inherent in a multivariate data analysis, and likely contributes more noise to the system. Another concern is Olsen's use of data from multiple analytical methods. To the extent that there is bias between analytical methods, it can result in non-random variability. Phosphorus was one such analyte, run by different methods, and by different laboratories. Bacteria and phosphorus are not secondary parameters in the analysis. They are in fact the two parameters cited in Olsen's summary PCA opinion, where he claims to have identified a "*distinct chemical signature that contains both phosphorus and bacteria.*"[122]

But most importantly, Olsen's PCA applied to this data set did not resolve sources because these chemicals are not conservative in the environment. That is, they do not behave similarly in an aqueous environment. Diagnostic chemical differences and ratios that might be observed in the original presumed source materials (i.e. poultry litter, cattle manure, and WWTP effluent) are not preserved once those constituents are in water. Olsen's analysis was doomed from the start because he assumed a geochemical system controlled by unchanging ratios of source-diagnostic chemicals/bacteria. As discussed in Section 4.0, the actual controls on this system are the degrees to which a few key chemicals (in particular total sodium, chloride, total iron and total aluminum) have a preferential affinity for dissolved phase, or tend to be associated with suspended particulate matter. Olsen has not discovered unique chemical/biological signatures related to poultry and WWTP effluent. Rather, his PCA does nothing more than distinguish between turbid water and salty water. To the extent that total phosphorus is explained by his analysis, it is because variability of total phosphorus is a function of its association with iron, aluminum and suspended particulate matter. The other key parameters in Olsen's supposed poultry signature (bacteria, copper, arsenic, and zinc[123]) exhibit an extremely poor fit in Olsen's model.

The use of mathematical techniques such as PCA carries with it the aura of precision and exactitude. The associated jargon and the fact that it is mathematically complex is daunting, such that somebody who understands the method a little can often intimidate a skeptic that doesn't understand it at all. But it is not magic, and it does not give one special powers to see things in the data that are otherwise unobservable. The mathematics of PCA may be objective and straightforward, but the interpretation is entirely subjective. It is therefore incumbent upon the

[122] Olsen (2008a). p. 2-1. 3rd bullet – final sentence.
[123] Olsen (2008a). p. 1-2 (3rd bullet), and p. 6-27.

data analyst to evaluate the efficacy of that interpretation in an open and honest manner. Olsen failed to do this. When we dig just a little deeper into his analysis, his theory of a source driven, poultry dominated system falls apart.

But in conclusion, putting aside the problems of assumptions, philosophy of data analysis, methodology and logic, consider this. Olsen's SW3 and SW22 PCA runs included 15 samples presumed or collected with intent of characterizing sources other than poultry (2 cattle edge-of-field; 3 cattle impacted springs; 4 WWTP; and 6 Tahlequah urban stream samples). Every single one yielded a PCA score which fits Olsen's criterion for exhibiting his *unique poultry waste signature*. Olsen's PC1 threshold is without a doubt, not unique and he has failed to establish a poultry-specific biological and chemical signature.